metal finishing

AINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING,
ALVANIZING, METAL SPRAYING and all METAL FINISHING PROCESSES

Vol. 3 No. 27 (new series) MARCH, 1957

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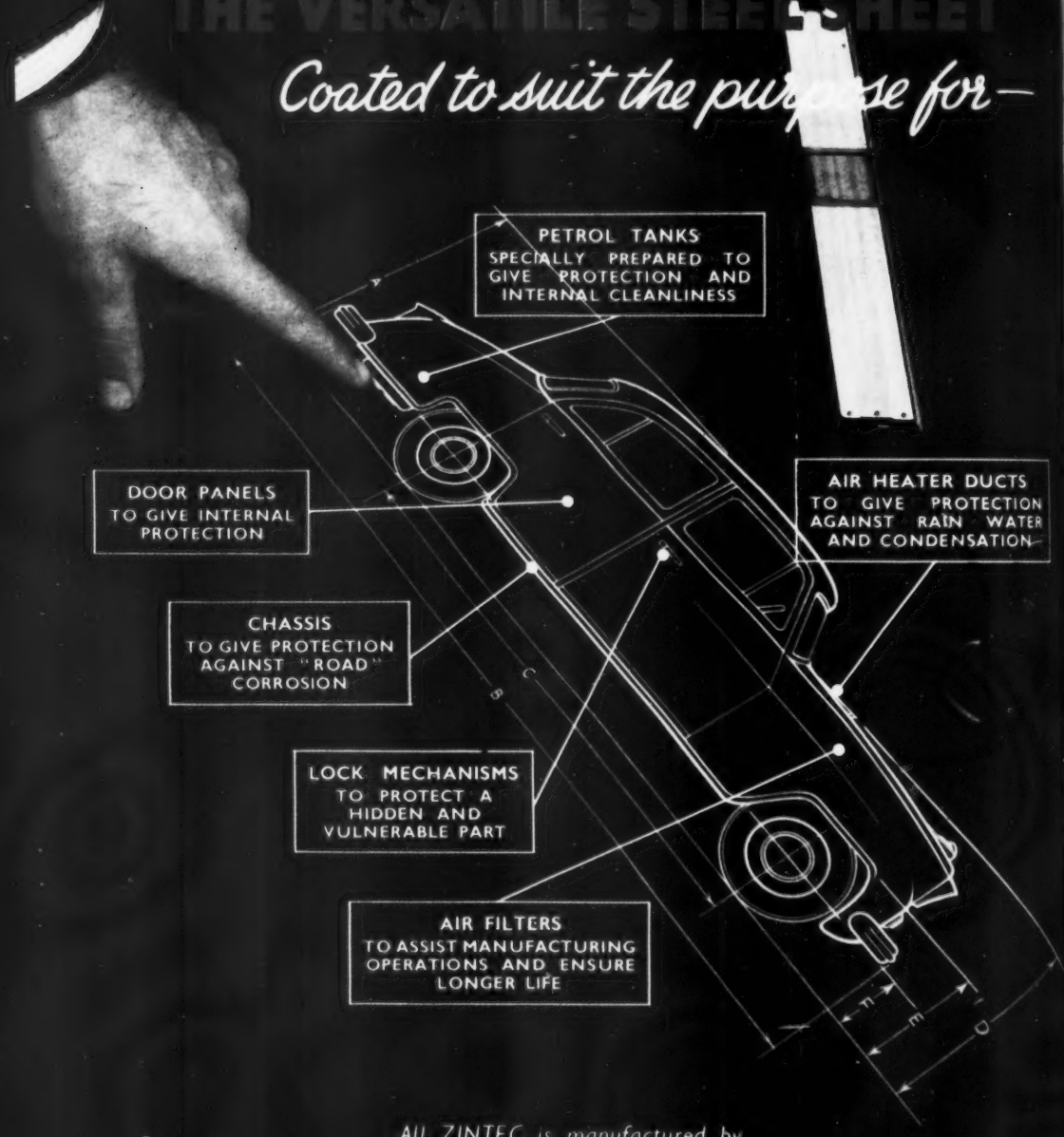
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metal finishing Journal

March, 1957 Vol. 3, No. 27 (New Series)

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THIS JOURNAL IS DEVOTED TO THE SCIENCE AND TECHNOLOGY OF PAINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, GALVANIZING, ANODIZING, METAL SPRAYING & ALL METAL FINISHING PROCESSES. THE EDITOR IS PREPARED TO CONSIDER FOR PUBLICATION ANY ARTICLE COMING WITHIN THE PURVIEW OF "METAL FINISHING JOURNAL" AND ALL SUCH ARTICLES ACCEPTED WILL BE PAID FOR AT THE USUAL RATES.

Contents

PAGE

"Glitter-Bugs" **97**

Talking Points **98**
"Platelayer

Molybdenum Disulphide as an aid to the Lubrication of Difficult Conveyors **99**
H. Peter Jost, A.M.I.Mech.E., M.I.Prod.E., Mem.A.S.M.E.

The Production of Electro-zinc Coated Steel Sheet at the New Plant of Margam Electro Finishes Ltd. **103**

Bright Nickel Plating. Co-ordination Compounds and the Plating Potentials of Metals in Relation to the Theories Propounded to Account for Bright Nickel Plating... ... ... **111**
Dr. I. R. Bellobono

Finishing Post **118**

Modern Paints and Their Application **119**
E. E. Coker

Cebelcor Commentary **122**

Coating by Thermal Diffusion **123**

Finishing News Review **128**

Plant, Processes and Equipment **132, 134**

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GLITTER-BUGS

A LETTER from a reader in this issue of METAL FINISHING JOURNAL *once again criticizes the poor quality of the chromium plating on the modern motor car, a criticism which has been made so evident in recent months by the variety of coloured lacquers used to offer additional protection against the elements. Complaints such as this, relating not only to the electroplated finishes but also to the paintwork, are many and frequent, but it should not be forgotten, to retain the problem in its true perspective, that there is a tendency, due to the peculiar functioning of the human memory, to regard everything in the contemporary scene as being inferior to that produced in the "good old days".*

The modern motor car is mass-produced, and the necessity to speed up its manufacture and also save materials, has involved the adoption of new techniques, both in body design and in the finishes applied.

The type of paint finish used today differs very considerably from that used before the war. Formerly it was the practice to apply a large number of coats of cellulose lacquer, each coat being heavily rubbed down after application. However, the need for this costly and laborious process has been eliminated by the introduction of the synthetic-resin-based paints, by the use of which an adequate thickness can be achieved in two coats. In addition, the small amount of reflowing which takes place during the stoving of the paint coating imparts a high degree of gloss which needs virtually no mechanical finishing. Furthermore, it is now standard practice to pretreat sheet surfaces with a phosphate process to enhance the paint bond and prevent the spread of rust from accidentally damaged areas. No doubt a future development, which will produce an even longer-lasting finish, is the use of phosphated electrozinc-coated sheets as now being produced in the new plant recently erected in South Wales.

As regards the nickel-chromium plating, more of this is used on a modern car than in earlier designs. This plating is applied to steel, usually with a copper undercoat, and to zinc-base die-castings. Much of it is deposited in large automatic plating plants in which the nickel is obtained in the fully bright condition as compared with the earlier batch processing methods and the use of dull nickel. It is unfortunate that during the whole of the post-war period the plating industry has suffered from inadequate supplies of nickel with the result that, in many cases, deposit thicknesses have been below that required for really adequate service. In addition there is evidence to show that the polishing operation, which was necessary on the older dull nickel plate, helped to close up pores in the coating. The omission of the polishing process on modern bright nickel plating may conceivably result in the presence of a greater number of pores, a condition which is also exaggerated by the abnormally thin coatings and, as a result, highly stressed deposits. But is the finish of the modern motor car inferior to that of the prewar models? The answer would appear to be that in every aspect of its production there exist improved techniques, equipment and materials, which can produce a superior article if properly applied.

To those, therefore, who draw unfavourable comparisons between modern times and the "good old days", it can be said that their memory is not as trustworthy as they suppose, or they have been unfortunate in encountering an example of inferior application of superior materials and processes.

Talking Points by "PLATELAYER"

TOPICAL COMMENT FROM THE MAIN LINES AND SIDE LINES OF METAL FINISHING

SOLVING PRESSING PROBLEMS

IF Coslett could but see the present-day ramifications of phosphating which he discovered just fifty years ago, he would be a very surprsied man indeed. On looking through a list of some of the more modern applications of the process which are not primarily for rust prevention at all, one finds that the developments in recent years have been little short of astounding. Indeed, it might well be that the non-protective applications of phosphating may become of greater importance than the better-known methods of pre-treatment before painting and for the rust-proofing of nuts and bolts, etc.

Phosphating treatments are now regularly used on steel rods prior to drawing into wire, on pressings for various types of steel containers, and lately even for the treatment of titanium sheet, which is notoriously difficult to cold form and where phosphating helps a great deal. In the case of stainless steels and heat-resisting alloys the number of interstage anneals can be markedly reduced by phosphate treatment before pressing or forming. The cold extrusion of steel is another process in which phosphating facilitates production, and this also applies to cold heading operations on rivets, nuts and bolts.

In all these instances, phosphating gives longer tool life, greater accuracy and smoother finishes. It is also claimed to speed up drawing operations, and to reduce power requirements, stoppages and material breakages. The fact that these claims are substantiated in practice is shown by the impressive number of users of these processes today.

TOO GOOD TO BE TRUE

A RECENT advertisement for a prominent bright nickel plating process marketed in the United States claims that "deposition rates with 'X' are 100 per cent. higher than those obtained with any other process . . .". The reader, in this country at any rate, would be frankly incredulous if he were confronted with a statement like this. Progress in an established industry like nickel plating does not take place by momentous bounds, but by a process of progressive development, and one might well beg leave to doubt whether any one nickel plating process is twice as fast as any other, particularly in America. While not knowing enough about this particular process to state categorically that this is not in fact so, I believe I should not be alone in being somewhat sceptical.

If I might plagiarize a well-known quotation on the subject of justice, it is not only necessary that advertising should be truthful, but it must be manifestly seen to be truthful. An advertisement claiming an increase of 50 per cent. in plating speed would probably have more "pulling power" than the one in question which may arouse doubts as to whether the advertiser's claims were intended to be taken seriously.

TORTOISES AND HARES

MOST people, if asked whether a company should promote an employee to an executive position because of his ability, would say that this is the obvious criterion on which to judge his suitability. Yet a recent study of methods of selection by the American Institute of Management indicates that ability is made the sole basis too often, and that other qualifications can be of equally great importance. Of these, integrity, which includes honesty and a sense of responsibility, and industry which consists of diligence and initiative, must be taken more into consideration. The importance of industry in a candidate has come to the attention of school examiners who have discovered that many children with a high intelligence quotient fail to make the grade because of a lack of application which no amount of intelligence will compensate for. Unfortunately, there is no easy method of assessing this quality except through a prolonged personal knowledge of the individual. More often than not a mentally less well-endowed person who works hard can be more effective than a lazy genius.

HEAVENLY FINISHES

THE earth satellite to be constructed in the United States for the International Geophysical Year looks like providing an interesting exercise for the metal finisher. The reports indicate that it is to be made of magnesium coated with gold and then with aluminium. Finally, a silicone finish is to be applied.

SHOWMANSHIP

Some important officials recently paid a short visit to a factory where the management were very proud of their automation. The visitors were, however, more than impressed by what they saw—they were astounded. Not one worker was in sight anywhere on the plant.

It transpired subsequently that they had chosen the tea break for their tour, but nobody had bothered to tell them!

MOLYBDENUM DISULPHIDE as an aid to THE LUBRICATION OF DIFFICULT CONVEYORS

by H. PETER JOST, A.M.I.Mech.E., M.I.Prod.E., Mem. A.S.M.E.*

THE vast majority of conveyors can be satisfactorily lubricated by standard lubricants, *e.g.*, oils and greases, either straight or compounded, sometimes with E.P. additives and occasionally graphited. The lubricant is in some cases applied intermittently, and in other cases it is continually applied by means of lubricators of various designs. In general, if such methods of lubrication produce satisfactory, even, and almost wear-free operation, then no change should be contemplated.

There are, however, a number of conveyors, particularly on painting and process work, which, due to a variety of causes, are difficult to lubricate. The exact nature of the causes which make a conveyor difficult varies considerably. It may be that a change of process involving a higher baking temperature (say 550° F instead of 250° F) creates conditions which were not contemplated at the time of erection; speeds are also often increased beyond the requirements for which a conveyor was designed; the conveyor may also have to pass over hot acids and alkalis, through washes, or Bonderizing chambers; all these features may create difficulties in lubrication with which standard lubricants cannot cope, particularly as the amount of lubricant that can be applied is often strictly limited particularly as in the case of most paint conveyors, a single drop of oil or grease will generally spoil the work.

Graphite in oil or in water is sometimes reverted to in order to overcome some of the difficulties; its use, however, has never been wholly satisfactory, largely due to the building up of the graphite and also due to speckling of the work. Nevertheless, the move towards a solid lubricant for conveyor and chain lubrication is a move in the right direction.

It is only natural that among other solid lubricants molybdenum disulphide should be considered as an alternative conveyor and chain lubricant.

Properties of Molybdenum Disulphide

Molybdenum disulphide is in appearance like graphite; it is a mineral. The world's largest deposits of molybdenum disulphide are in Colorado, where the majority of the material is mined. Before being usable as an industrial lubricant, however, it has to be purified and refined; in fact its purity generally controls its effectiveness in application. The examples mentioned in this article all refer to the most highly refined material purified by special processes and manufactured in large numbers of types and compounds by K. S. Paul (Molybdenum Disulphide) Ltd., Park Royal Road, London, N.W.10, under the Trade Mark "MOLY-PAUL".

The basis for the lubrication action of MoS_2 lies probably in its molecular structure. Every lamina of the compound is composed of a layer of molybdenum atoms with a layer of sulphur atoms on each side. Due to the weakness of the sulphur-to-sulphur bond these laminae slip easily over each other (Fig. 1).

On the other hand, the outer layers of the MoS_2 are adsorbed to the surfaces of the sliding metals; to break their bond requires great force, and it is this feature which is believed to account for the capability of MoS_2 to withstand pressures of up to 400,000 lb. per sq. in.

With ordinary oil lubrication, metal-to-metal contact occurs on the high spots of rubbing surfaces. In consequence these contacts weld momentarily together. To separate them requires forces greater than the shear forces of the "weld". In contrast to this MoS_2-lubricated surfaces prevent metal-to-metal contact; instead the pressure exerted by *meeting* high peaks is believed to cause plastic deformation below the MoS_2 face, such deformation requiring a much lower force, releasing less heat and causing no surface damage. This results in a lower coefficient of friction than with other boundary lubricants.

As MoS_2 is a solid film, it cannot "lose" viscosity as happens so often when lubricating oil is used at high temperatures. MoS_2 is not generally affected under temperatures of 800° F. In the absence of air it will not oxidize at temperatures of up to 2,000° F.

Molybdenum disulphide is chemically inert, it withstands the action of most acids; exceptions are

* *Director, K.S. Paul (Molybdenum Disulphide) Ltd.*

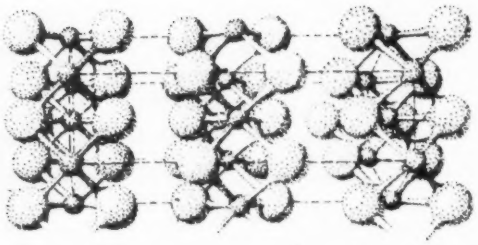


Fig. 1. (*a*) (left): *The structure of MoS_2. The small spheres represent molybdenum atoms and the large spheres sulphur atoms. Each molybdenum atom is surrounded by six sulphur atoms at the corners of a triangular prism.*
(*b*) (above): *Functional illustration of the laminar structure of molybdenum disulphide.*

"aqua regia", boiling hydrochloric acid, fluorine and chlorine. Hydrofluoric acid does not affect it.

Molybdenum Disulphide as Lubricant for Conveyors

From these properties molybdenum disulphide would appear well suited for the lubrication of difficult conveyors, in fact for some years now, MoS_2 in water has been tried for conveyor and chain lubrication. While some improvements were recorded, results were inconsistent and on the whole could not be regarded as having solved the problem. Oil was also tried as a carrier, but led to carbonization and other undesirable features. The failure of these trials were in the main due to three causes; these are:

(*a*) insufficient purity;
(*b*) wrong particle size;
(*c*) incorrect carrier.

The questions of purity and particle size are of considerable importance, the former because impurities contained in the ore which are not removed by flotation are usually silica, or of a silicious nature, and the latter because best adsorption is usually obtained only if the particle size and distribution of the molybdenum disulphide is the right one for the material and application.

Of equal importance is the question of the vehicle to be used, as MoS_2 in its natural form (powder)—even if pure and of correct particle size—cannot suitably be employed as a conveyor lubricant.

After extensive research several pastes and liquids have been evolved for use on difficult conveyors. The *pastes* contain a large concentration of pure MoS_2 (approx. 70 per cent.) compounded by means of a special process with a balanced ratio of additives and members of either polyalkylene glycol or silicone, or other families ("Moly-Paul Grades U and 77). The *liquids* consist of a low concentration of the purest MoS_2 of near colloidal size (approximately 50 per cent. under $\frac{1}{2}$ micron and 85 per cent. under two microns) in one of the large polyalkylene glycol family with a combination of appropriate additives and balanced by a stabilizer ("Moly-Paul" 30). While from a point of view of effectiveness, a near colloidal dispersion has been found considerably more effective than a colloidal dispersion, application considerations make it sometimes desirable to utilize a colloidal particle size, in which case the carrier is either oil ("Moly-Paul" 55) or a polyalkylene glycol ("Moly-Paul" 40), the mixtures being held in dispersion by means of special stabilizers. These special lubricating compounds have solved a very large range of problems connected with difficult conveyors.

Experience with Molybdenum Disulphide Conveyor Lubrication Compounds

1. *Continuous Pickling Plant Conveyor*

At the works of a refrigerator manufacturer the continuous conveyor, taking refrigerator bodies through stripping and pickling tanks, gave considerable trouble, mainly due to breakage of linkages, leading to jamming.

The work passes through the following 10 tanks:

1. Hot alkaline cleaner.
2. Cold rinse.
3. Hot caustic cleaner.
4. Warm rinse.
5. Warm rinse.
6. Sulphuric-acid pickle (hot)
7. Cold acid rinse.
8. Hot nickel immersion
9. Cyanide solution.
10. Neutralizer.

As can be seen from Fig. 2, the conveyor is in places only 12 to 18 in. above the liquid, *e.g.*, hot sulphuric acid or hot caustic soda.

An investigation showed that the breakage of arms, levers, etc., was caused primarily by lack of lubrication, causing seizures and undue strain.

Many lubricants were tried before a complete solution was found by the application of the standard conveyor paste ("Moly-Paul" Grade "U") to the ball bearings and all mating faces, and the standard conveyor liquid ("Moly-Paul" 30) for dripping on to the track. At the time of writing this conveyor has been operating for over 12 months without maintenance, save the fortnightly or monthly application of the conveyor lubricant.

Bonderizing and Painting Conveyor

At the same factory lubrication of the main Bonderizing and painting conveyor presented some difficulties.

This conveyor is of the power pull type; it is 1,800 ft. long and operates on two levels approxi-

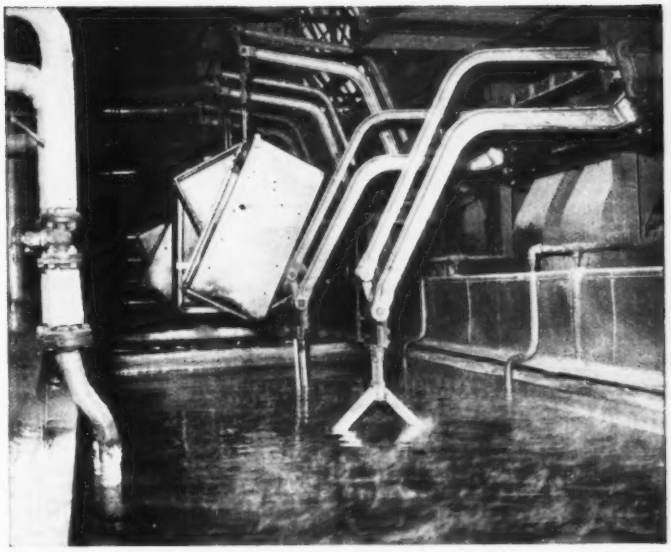


Fig. 2.—Part of a conveyor line operating over stripping and pickling tanks where in places the linkage approaches as close as 12 in. to the surface of hot solutions of sulphuric acid or caustic soda.

mately 20 ft. apart. In addition to the Bonderizing chambers, it has to pass through heated ovens (450° F). Oils with and without graphite had been tried, and although these were effective when first applied, the improvement did not last long; carbonization was a considerable problem when graphite was used and small black spots were found on the refrigerator bodies.

After successful application of the standard conveyor paste to the continuous pickling conveyor (*see* above), the same compound was applied to this conveyor and the results were satisfactory. The wheels no longer went solid and, instead of moving jerkily, the conveyor moved very smoothly; conveyor power consumption also decreased considerably.

The paste requirements are very low. It is of interest to note that during the early stages of application an increase in power consumption and a number of "solid" wheels were noted.

Investigations showed that the greaser thought that the new conveyor paste was the same as graphited grease and filled the bearings completely. As the paste consists of approximately 70 per cent. pure MoS_2 (a solid) the movement of the balls in the bearings soon became impossible. A small amount of standard conveyor liquid cured the trouble, and one shot only is now applied per bearing per month.

Lubrication of Oven Chain

At a well-known Northern bakery, the oven chain lubrication of a Baker-Perkins confectionery oven was a constant source of concern to the maintenance department.

The oven operated 24 hours per day at temperatures of 500 to 600° F. Conventional lubricants gave rise to an accumulation of carbon deposits when the carrier used was oil and external graphite build-up with internal corrosion when graphited water-based lubricants were used. Both types of conventional lubricants caused "dog-legging" of the chains together with general link stiffness.

Manual wire brushing of the chains followed by brush application of "Moly-Paul" 30 showed immediate improvement in chain flexibility and its subsequent use has resulted in a highly satisfactory condition of the chains. The application of Grade 30 is now usually made once per month, but this period is sometimes exceeded with no detriment to chain flexibility. The appearance of the chains following the use of "Moly-Paul" 30 is a slate-grey without any of the deposits normally associated with oven chains using conventional lubricants (Fig. 3).

The controlled use of molybdenum disulphide ("Moly-Paul" 30) at prolonged periods only compares favourably in respect of cost against the more frequent applications necessitated when conventional lubricants were used, particularly as the resulting chain condition showed great improvement and there is also a saving of power.

Light Conveyor (Rinsing, Pickling, Painting, Stoving)

The conveyor at a works manufacturing light steel pressings was subjected to the following treatments:

(*a*) Degreasing.
(*b*) Cold rinse.
(*c*) Neutralizer (hot).
(*d*) Cold rinse.
(*e*) Chromate (hot) treatment.
(*f*) Baking oven at 200° F.
(*g*) Paint dip.

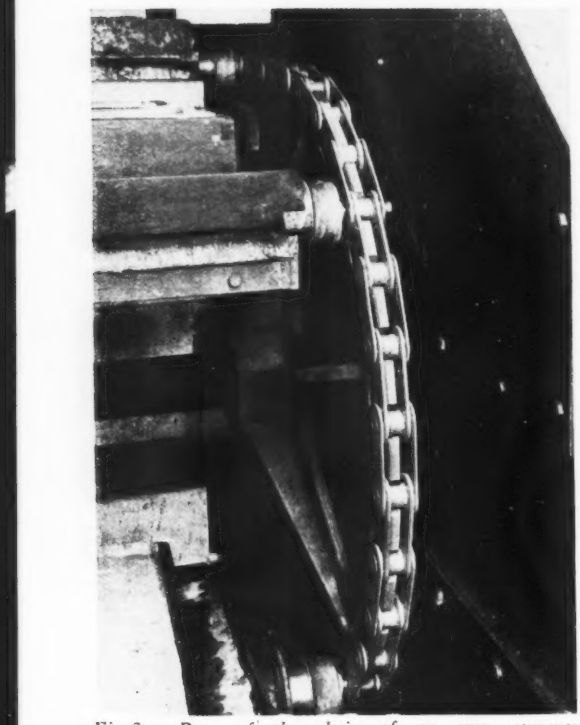


Fig. 3.— Part of the chain of an oven conveyor operating at 550 to 600° F. The clean appearance of the links is clearly evident.

(*h*) Stoving oven at 300° F.

At Stage (*c*) a jet of water is directed against the work and conveyor.

Lubrication of this conveyor is satisfactorily effected by means of an air-mist lubricator which now blows a mixture of oil and colloidal molybdenum disulphide ("Moly-Paul" 55) on to each side of the links (*see* Fig. 4). The total consumption of lubricant is in the neighbourhood of ½ pint per 24 hours, 10 per cent. out of which is the colloidal dispersion of pure MoS_2.

Miscellaneous Applications

The use of highly refined MoS_2 is, however, not limited to chains and to ball and roller bearings. The application of the high concentrate paste ("Moly-Paul" Grades U or G) to threads has prevented thread welding and seizure at temperatures as high as 1,700° F; applied regularly to the driving sprockets, it has virtually eliminated their wear.

Often a single application of a high concentrate cured troublesome plain bearings, and on power screws and worms it is known to have reduced the required driving power by up to 40 per cent.

Gear scuffing and galling have been prevented, and scuffed and galled teeth cured by the application of the high concentrate compound ("Moly-Paul" Grade G).

Due to its metal impregnating characteristics, it has become a boon to fitting shops, making assemblies much easier and preventing scoring during key fitting, on splines and many other parts.

Sintered materials and plastics impregnated with MoS_2 have shown remarkable heat resistance and long life qualities.

Conclusion

While molybdenum disulphide is not a cure for all ills, it has been found most useful in overcoming many troublesome and difficult features of conveyor operation and maintenance.

Its use will greatly assist in keeping capital and power use between the levels dictated by economic necessity and the consequences of Government financial policy.

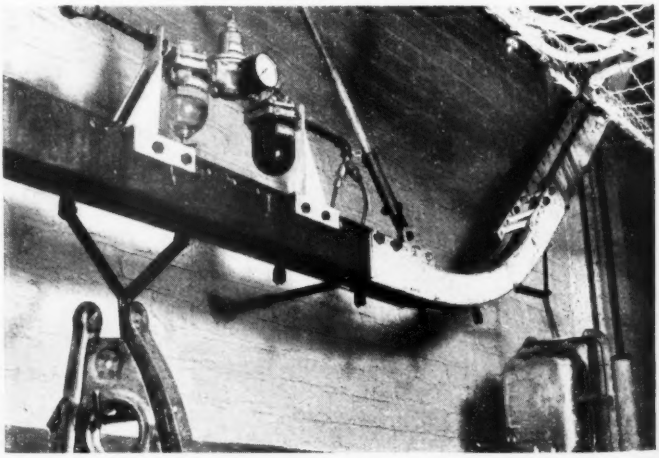


Fig. 4.—(Right) Equipment for the continuous spraying of a colloidal dispersion of molybdenum disulphide in a thin oil on to each side of the links of a conveyor by means of a micro-fog lubricator.

The Production of

BONDERIZED ELECTRO-ZINC COATED STEEL SHEET

at the New Plant of Margam Electro Finishes Ltd. *

TO combat atmospheric corrosion of sheet steel, zinc coatings are in greater demand than any other metal coating. Related to the protective value of zinc it is universally accepted that the rust-arresting life of the metal is proportional to the coating thickness irrespective of how applied.

Solving the Rust Problem on Sheet

The usage of sheet steel coated at the rolling mill is growing in volume yearly and new markets are developing, in particular for electro-zinc-coated sheets. This product meets most general and special-purpose requirements in the sheet trade, for in the finishing process the physical performance of the steel is not in any way altered, compared with the Sheradizing and hot-dip galvanizing processes. It should be appreciated that the properties and coating thickness of electro- and hot-dip galvanized sheet differ in many respects and, therefore, each has its own particular field of application.

The surface properties of electro-zinc-coated sheet remain intact through fabricating or drawing operations; annealing does, however, destroy the coating. Rusting during transit is eliminated and also as an unfinished component while in store. The surface does not require any extra preparation for welding, soldering, spinning, forming or drawing operations.

The Finished Product

The presurface treatment of the electro-zinc coating at the mill by Bonderizing further increases the range of applications; for Bonderizing, which is a proprietary phosphating process, increases paint adhesion and thereby produces a more durable protective system.

* The products of the company are being marketed under the registered trade-mark "MEFCO."

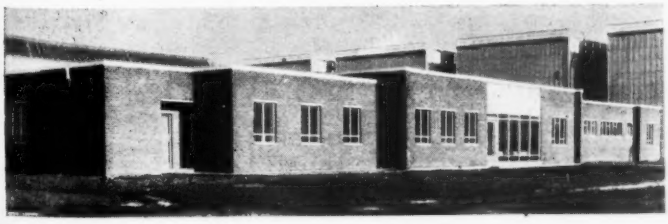


Fig. 1 (*above*).—*General view of main factory building of Margam Electro Finishes Ltd.*

Fig. 2 (*left*).—*General view of administration/laboratory block*

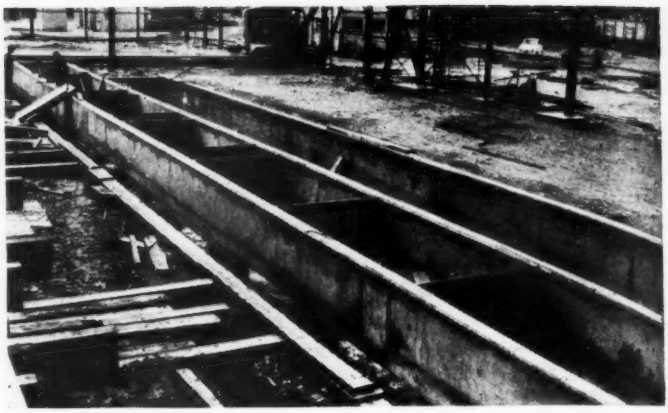


Fig. 3.—Photograph taken during construction of the plant. This shows the sump, 134 ft. long and 7 ft. 4 in. wide. The sump, which is carried on piles, is in the main plating line pit

Designed to meet the growing demand for Bonderized electro-zinc-coated sheet, a new company, Margam Electro Finishes Ltd., situated within the Steel Company of Wales Ltd., Abbey Works, have built a factory to house the most up-to-date plant of its type in the world.

The plant embodies many interesting features, including:

Automatic control of electric current to maintain current-density which provides predetermined coatings of required thicknesses.

Continuous roller conveyors to feed and discharge sheets at a speed capable of continuously handling the optimum output of the electrolytic section.

Electrolytic cell construction of non-conducting material to eliminate current losses during the plating process.

Unhindered accessibility of all mechanical, electrical and fixed plant.

One hundred per cent. utilization of the costlier capital plant, in particular electrical ancillaries, including regulators and rectifier units, giving a total input to the plant of 33,500 amp. at 12 volts.

Building Project and Plant Civil Work

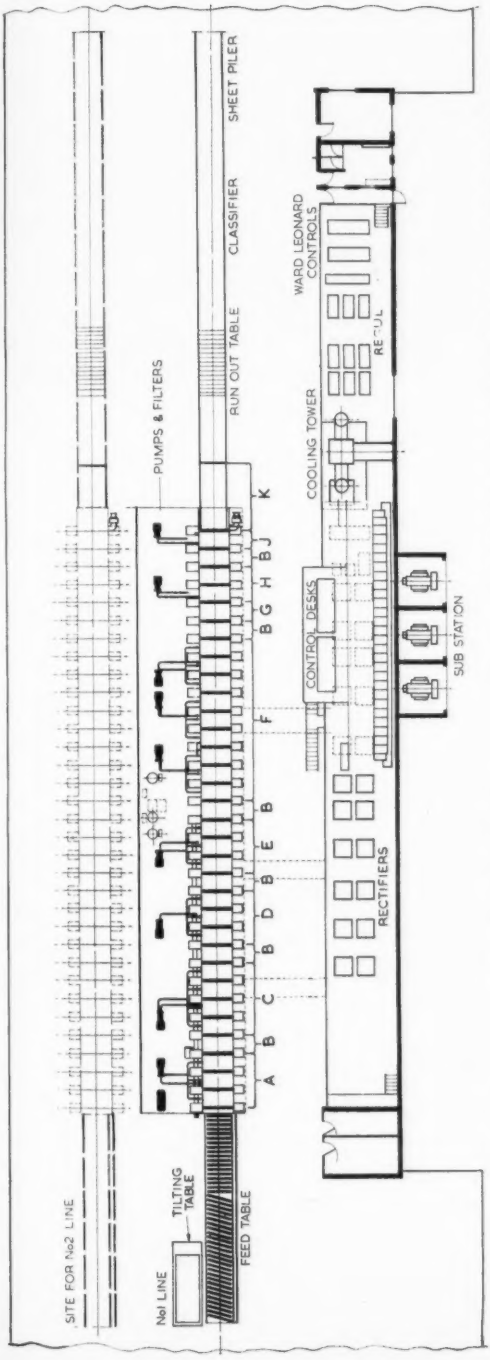
Two buildings have been erected, one the factory (Fig. 1), the other the administration/laboratory block (Fig. 2).

The plan of the factory building is channel shaped all-steel construction on unpiled foundations, and is comprised of five integral sections. The South and North wings, reception and despatch bays respectively, are 110 ft. long, 72 ft. span, and 34 ft. to the eaves, and are constructed of four all-welded Warren-girder type frames. Natural lighting is derived from patent glazing at the eaves, which extends the whole length of the bays, while the roof decking is troughed aluminium sheeting covered by Tentest board, two layers of bituminized felt, mineral finish, and limestone chippings. There are two electrically operated doors on the East end of each of the bays, allowing unhindered passage of transport.

Part of the South bay accommodates compounds constructed of wire mesh screens to be used for stores, workshops and anode-casting shop. Also in this wing are a tilting table and acid storage tank. The North end is the despatch bay in which a weighbridge is installed, the remainder of the floor being used as a stocking area.

The centre bay is 240 ft. long, 75 ft. span and 27 ft. to the eaves, the main frames being of similar construction to those of the wings. Natural lighting is derived from the roof (North light) and high-level side glazing. The North-light roof is formed by cranking the purlins which are continuous over the main frames, consequently giving a very clean appearance and economizing on the use of structural steelwork. The glazing on the North side is approximately 20 deg. to the horizontal, whereas the South side is approximately 70 deg. to the horizontal, containing adjustable aluminium louvres positioned immediately over the plating line below.

This bay contains the plating line pit, housing plating sump, pumps, pipework, etc., and is the only part of the structure which is piled. The sump (Fig. 3) is constructed as a continuous reinforced concrete structure approximately 134 ft. long and 7 ft. 4 in. wide, with division walls separating it into individual baths. All sections have an acid-resisting membrane which is protected with acid-resisting brickwork bedded and jointed in the relevant compound, depending on the contents of the individual baths. Walkways are supported from the sides of the sump. On top of the sump sit the cells, 7 ft. 1 in. wide and 3 ft. long, precast in reinforced concrete with cast-in bolts for levelling legs and end plate fixings in F.M.B. quality stainless steel (Fig. 6). Acid and wash-water cells are protected by an asphalt membrane in three layers giving a total thickness of approximately 1 in.



To the East of the centre bay and parallel with it is the rectifier room (Fig. 7) with toilets and offices at either end. The rectifier room is 4 ft. below general floor level and coincides with the floor level of the plating-line pit, the two being interconnected by busbar trenches. Plant access to this room is through two hand-operated roller shutter doors. The windows are positioned at high level above the three transformer bays on the outside and at sill height in the switch and control rooms which are above the rectifier room.

The switch and control rooms occupy an area of approximately 60 ft. by 16 ft., the floor slab of the control room portion being higher than that of the switch room and cantilevered into the centre bay of the building. The switch room is bounded on one side by a brick wall, and on the other three by a fire-proof screen. A fire-proof false ceiling has been suspended below the aluminium roof decking, and the floors of both rooms finished in red granolithic concrete with construction joints in ebonite strips. Doors from the switch room lead into the main stairway from the factory floor to the control room. The front of the control room is an observation window enabling the control-desk operators to view the whole of the plating line.

The building is tastefully decorated with acid- and alkali-resisting paint, parchment colour above the 7-ft. dado and orchard green below, the whole giving an atmosphere of air and light.

Acid Disposal

A building for the disposal of liquid plant effluent is situated West of the office block, with the effluent being pumped to it from a holding chamber located immediately South of the plating-line pit. The pit is sheet piled due to the nature of the ground, and is of reinforced concrete and lined construction.

The disposal building consists of a series of reinforced concrete tanks through which the effluent passes until rendered innocuous.

General Description of Process Line

The plant consists of several integrated sections which complete the 10 main operations. In general, the process line takes the form of a combined continuous roller conveyor and electrolytic plating line with conveyor controls at the feed and out-going end, placed at 12-in. pitch assisted by intervening gravity rollers. In the electrolytic or centre section of the plant the drive rolls are placed at 4-ft.

Fig. 4 (*left*).—*Diagram of main processing line*

LEGEND

A — alkaline clean
B — water wash
C — electrolytic clean
D — pickle
E — electrolytic pickle
F — electroplating zinc
G — inspection
H — Bonderize
J — chemical rinse
K — drying section

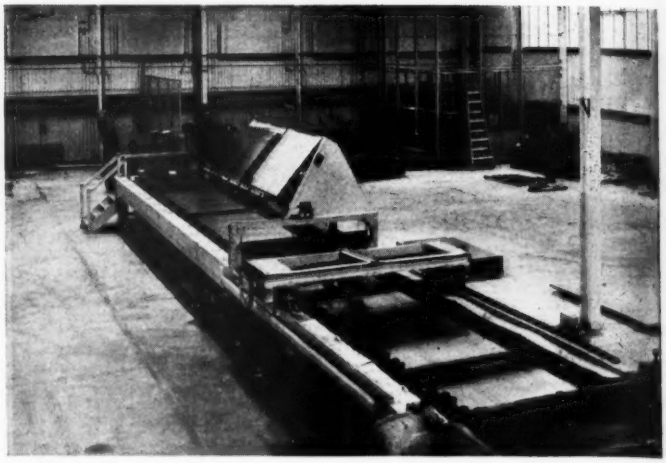


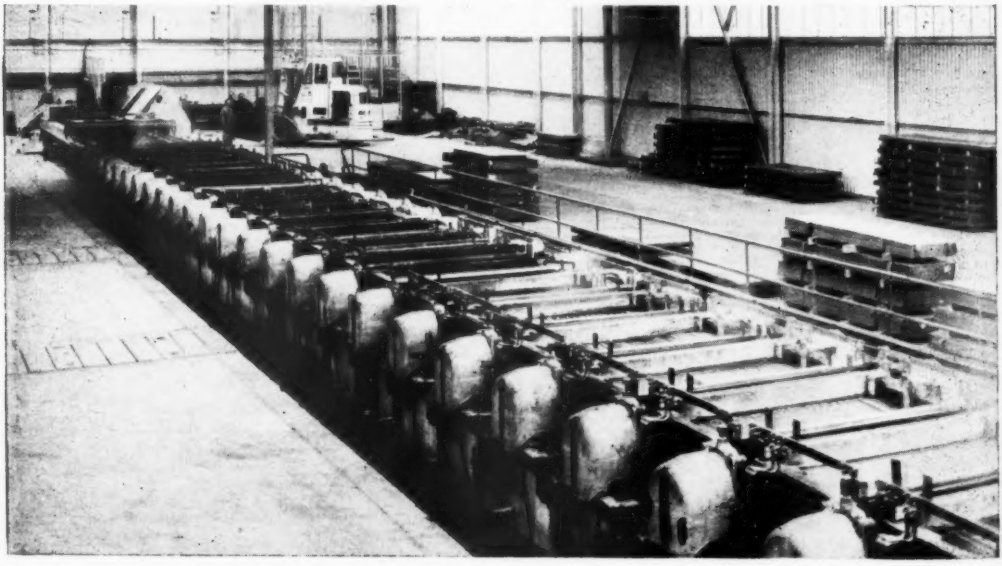
Fig. 5.—Close-up of feed section of processing line. The hydraulically operated table, in the background, is shown in the tipped position from which the sheets are fed on to the roller table

centres and are stainless-steel sheathed. Located above these are rubber-covered rolls which are hydraulically operated. The width of the track is approximately 5 ft. 6 in. over the rollers and the sheets are maintained in a straight line by guiding into the electrolytic section of the plant on one edge along needle rollers, which may be adjusted to suit the width of the sheet being handled. The whole of the plant track is mounted at a height of 3 ft. from the floor level. Each pair of drive rolls is an independent unit driven by a side shaft which is powered by three 15-h.p. motors and controlled through a Ward-Leonard unit (Fig. 8).

Feed Section

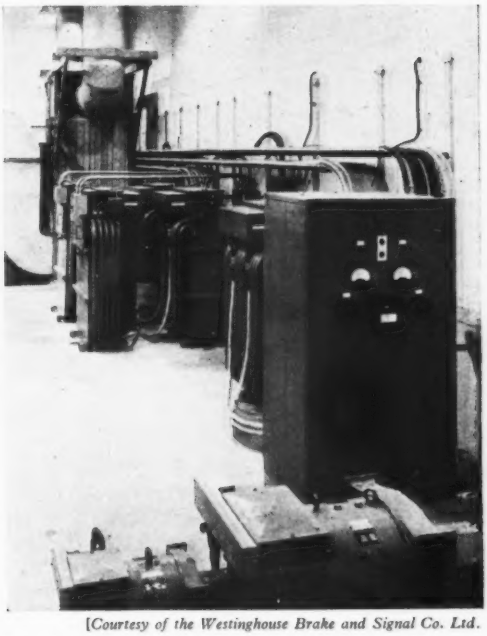
Sheets of the customers' desired size and quality are first placed on a hydraulically operated table which moves on its axis to an angle of 80 deg. (Fig. 5). The sheets are then flipped by hand on to a series of rubber-covered rollers running diagonal to the sheet width at a 75-deg. angle to the centre-line. When in motion these rolls automatically pull the sheet on to a series of needle rollers which, being preset to half the sheet width, line the sheet up accurately to the centre of the plant. The sheet then passes on to a secondary bed and under an electro-magnet which automatically

Fig. 6.—General view of the electrolytic section of the processing line, showing the individual cells



[Courtesy of the Westinghouse Brake and Signal Co. Ltd.

Fig. 7.—Part of main rectifier room



[Courtesy of the Westinghouse Brake and Signal Co. Ltd.

Fig. 8.—Ward-Leonard control unit, main control amplifier and regulators

operates a gate in conjunction with the gauger head. To the gauger head is attached a spring-loaded indicator roller which is hand positioned by the traversing mechanism, as required, by varying lengths of the sheet. The gate will fall below sheet level immediately the sheet passes the gate, thus preventing the next sheet on the feed section from passing. An indicator wheel on the gauger head is still on the sheet, which on passing allows the indicator wheel to fall. This action energizes a magnet and the gate is raised, allowing the next sheet to pass below the gate. The cycle is repeated

Fig. 9.—General view of processing line from exit end. On the right is the special fork-truck crane used for sheet handling, anode removal, etc., etc.

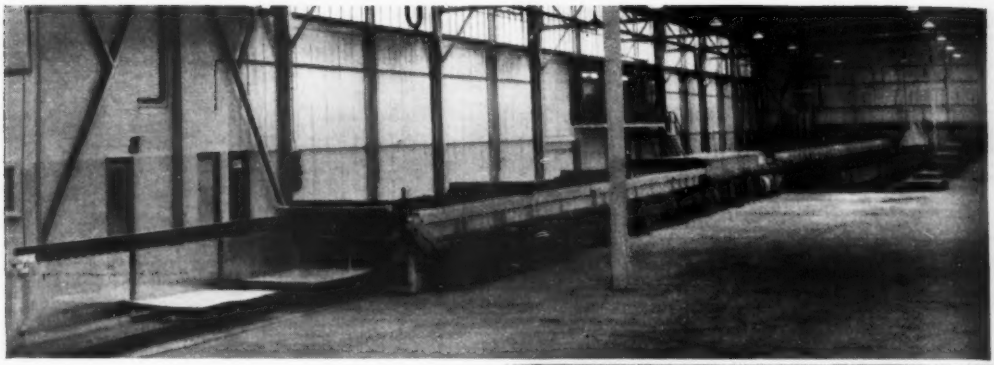


Fig. 10 (above).—Further general view of processing line from the exit end showing the position of the control balcony relative to the line. In the right background can be seen the steps leading down into the main pit in which are situated the pumps and filter units

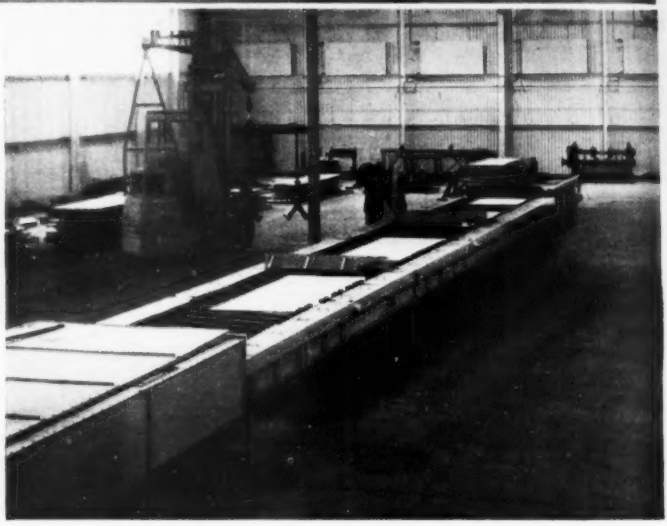


Fig. 11 (right).—Exit end of line showing end of drying section (foreground) and classifying and sheet-piling sections

and ensures an interval of required distance between each sheet as may be predetermined and this eliminates the possibility of over-lapping before it enters into the first process stage.

Process Cells

Each stage consists of a number of process cells; there are 32 cells (*see* Figs. 4 and 6) located between drive rolls, positioned at 4-ft. centres. The cells, which are specially designed, are made of precast concrete which has been vibrated in manufacture. Into the concrete structure are inserted stainless-steel holding studs. These locate the various plastic assemblies which guide the sheet through the plant. The cells, which contain the acid-etching and plating electrolyte, are completely covered with a specially formulated high-temperature asphalt membrane. This is acid resistant and will not conduct electricity.

Stage 1 (*Cleaning*)

The first operation in preparing the surface, is in passing the sheet through a heated alkaline cleaning solution to remove excess residual oil and loose solubles.

Stage 2 (*Cleaning*)

After rinsing, the second cleaning operation takes place in a stronger alkaline solution through which current is passed. This removes the more tenacious oily residues.

Stage 3 (*Acid Pickle*)

A further rinsing operation is carried out and the sheet passes into a dilute sulphuric-acid bath to remove oxides and rust.

Stage 4 (*Electroetch*)

The sheet is again rinsed and passes through a sulphuric-acid electrolyte to remove excess oxidation and minutely etch the steel surface.

The total length of the alkali/acid cleaning section is 68 ft.

Stage 5 (*Electroplate*)

The sheet then passes into the plating section, consisting of nine cells with a total plating length

Fig. 12.—Main control desk on control balcony. As can be seen, a full view from end to end of the processing line is obtained through the windows

of 36 ft.; in these the electrodeposition takes place and zinc is coated on to both sides of the sheet, to the desired thickness.

It is possible by adjustment of the plating cells to apply a coating on to one side of the sheet only, and the coating thickness can also be varied in thickness as required on either side of the sheet.

In connexion with the electrolytic section a complete room, which is situated 4 ft. beneath floor level, houses all drive control motors, water cooling unit for the rectifiers, transformers, regulators and rectifier units. The rectifiers are all of the oil-immersed type, water cooled.

Stage 6 (*Chemical Treatment*)

A rinsing operation is then carried out and the sheet passes through a spray and brush Bonderizing section, to form, on the zinc surface, a very finely crystalline phosphate film, which is a considerable aid to paint adhesion. Bonderizing is followed by a chromate spraying operation.

Stage 7 (*Chemical Seal*)

For some applications, the Bonderized coating is not required, and a further special chemical sealing treatment is found necessary, which considerably reduces oxidation and white-rust formation.

Stage 8 (*Drying*) (see *Fig.* 11)

The sheet then proceeds through the drying section which is in the form of a drying oven, steam heated by means of coils from the underside. Forced hot air is ducted to both sides of the sheet by a 2,500-cu. ft. per min. fan. On progressing, the sheet then passes through a cooling section and the forced air procedure is repeated, minus the heaters. The same fan pulls the cold air through this unit before it reaches the heaters in the drying section, the purpose being to bring the sheets to an ambient temperature.

The maximum temperature reached at any one stage, including the drying oven, is 140° F.

Control of Process Line

Situated above the rectifier room is a double step mezzanine floor or gallery. The lower section houses all incoming switch-gear and the higher level, which extends into the main shop and is enclosed by a steel/glass partition, locates the control desk (Fig. 12) from which the operator has a complete view of the plant. Operating on the automatic plant setting, when the first sheet reaches the first cell in the plating section or each group, its arrival is automatically recorded. The current is built up in accordance with the linear speed through the cells up to a maximum preset value, which is reached when the front of the sheet reaches the end of the last cell. An indicator system is embodied in the control desk which in effect records the passages of the sheet near the first rolls of the group of cells. By this means a constant current density is achieved so that the current is raised as the first sheet passes through the cells and so increases the area to be plated, and falls as the end of the last sheet passes through. Should there be an undue gap between adjacent sheets, the current will be reduced so that constant current density is maintained. The whole of this is operated by adjustment and the setting of the

(*Continued in page* 110)

Production of Coated Steel Sheet

(*Continued from page* 109)

control switch mounted on the control panel. It also determines the proportion of full-load current at which the rectifiers will operate. The setting of the control is determined by sheet width, deposit thickness, and speed of the line.

In addition a separate manual control is incorporated in the desk with an interlock switch from the automatic section. This is to facilitate continuous operation when the automatic control requires maintaining.

Stage 9 (*Inspection*)

The inspection section is 15 ft. long. Both the top and bottom surfaces of the sheet are viewed by the inspector in one operation. Mirrors are located on the underside area. The inspector grades the finished sheets by means of selector switches.

Stage 10 (*Classifying Section and Piling Section*)

This section is 35 ft. long, with driving and gravity rollers as previously described. Fixed needle guides are provided and a pair of 10-in. diameter rubber-covered rollers at the end of this section eject the sheets at a sufficiently high speed to give them an impetus when they reach the gravity rollers in the next section. This section will have two classifiers to discharge sheets of two different grades selected by the inspector. Each classifier consists of a section of carrying rolls which are allowed to drop and thus discharged sheets fall on to a pallet below the table.

The sheet-piling section is 30 ft. long and consists of two lines of 30-in. long gravity rollers mounted on a frame at a sufficient height from the floor level to receive a pallet on to which the sheets are piled. The total length of the line is 298 ft.

The plant is designed to process sheets up to maximum of 180-in. long by 60-in. wide in gauges 24 to 10 B.G. Coatings can be applied up to 0·0005-in. thickness on both sides and the plant will run at a maximum speed of 60 ft. per min.

Acknowledgments

Acknowledgment is made to the directors of Margam Electro Finishes Ltd. for permission to publish this article, and thanks are expressed to Mr. Gerald Adey, the company's general manager, for his assistance in its preparation.

Main Contractors

Acalor (1948) Ltd., Acid-resisting Brickwork and Effluent Treatment Plant.
W. S. Atkins and Partners, Main Consultants. Civil Engineers.
Brentford Transformers Ltd., Electric Regulators.
W. Canning and Co. Ltd., Continuous Electro-coating Section.
The Costain Concrete Co. Ltd., Specialized Precast Concrete Sections.
Dawnays Ltd., Structural Steelwork.
Equipment Repairs Ltd., Hydraulic Lifting Equipment.
The General Electric Co. Ltd., Drive Unit and Speed Control.
Gilmours (Wales) Ltd., Painting Contractors.
J. W. and E. Morris and Son Ltd., Electrical Contractors.
William Press and Son Ltd., General Fabrication and Pipework.
Ransomes and Rapier Ltd., Mobile Handling Equipment.
The Rimer Manufacturing Co. Ltd., Mechanical Sheet-handling Equipment and Drying Oven.
Andrew Scott (Civil Engineers) Ltd., Civil Engineering Work—Factory and Building.
Troughton and Young (Heating) Ltd., Heating and Ventilation.
The Westinghouse Brake and Signal Co. Ltd., Rectifiers and Control Gear.
Williams and Williams Ltd., Windows.
Film Cooling Towers (1925) Ltd., Cooling Tower.
Brentford Transformer Co. Ltd., Regulators.
Val de Travers (Asphalt) Co. Ltd., Asphalt covering.
Detel Products Ltd., Acid-resisting Paint.
Goodlass, Wall and Co. Ltd., Structural and Building Paint.
The Morgan Crucible Co. Ltd., Oil-fired Furnace.
Coopers Roller Bearings Co. Ltd., Bearings.
Crompton Parkinson Ltd., Oil Circuit Breakers.
Evershed and Vignoles Ltd., Servo Units.

TESTING FILTERS FOR VENTILATION

New British Standard Specification

PREPARED under the authority of the Mechanical Engineering Industry Standards Committee, a new British Standard Specification (B.S. 2831 : 1957) deals with methods of testing air filters used in air-conditioning and general ventilation plants. Two testing methods are described for efficiency and a test for dust-holding capacity and gravimetric efficiency is also included. Information is also given on such aspects as test rigs, calculation of results, apparatus for the production of test dust, etc. The standard is fully illustrated and also contains four appendices, one of which lays down a specification for esparto paper; a second provides a worked example of the method of calculating the value of methylene-blue efficiency. Copies of the standard may be obtained from the B.S.I., at 2 Park Street, London, W.1.

BRIGHT NICKEL PLATING

Co-ordination Compounds and the Plating Potentials of Metals in Relation to the Theories Propounded to Account for Bright Nickel Plating

by Dr. I. R. BELLOBONO *

WHEN use is made in chemical phraseology of the term "coordination", there is meant a kind of bond between atoms which was first conceived in 1893 by Alfred Werner(1) who subsequently devoted the remaining years of his life to the study of those entities which he called "complex molecules". The hypotheses propounded by him in explanation of the results obtained from his researches are incorporated in the theory of "co-ordination compounds" which permits of a simple comprehensive explanation of the chemical constitution of similar and non-similar types of complex metal salts, including hydrated and amino derivatives, mordent dyes and even some mineral dyes. Similar compounds had already been noted for the first time by Werner and it had not been possible to explain their formation on the basis of the older valency theories. Such substances were usually formed from simpler compounds in which the elements had already entered into combination together, operating at the usual valencies of the periodic system.

For example, hydrochloric acid combined with ammonia to form the "molecular compound" ammonium chloride. This at first was considered as the product of a "residual affinity", regarded as a force of different nature from ordinary valency possessed by the hydrochloric acid and ammonia respectively.

Werner examined a large number of chlorides of amines, which are compounds similar to ammonium chloride, although usually of much more complex molecular structure, and demonstrated that these all could be formulated on new principles.

The Theories of Coordination Compounds

The basic idea of Werner's theory was that the ability of an atom to combine depends not only on the nature but also on the number of the atoms or groups with which it is associated.

It is this number which he termed "coordination number", rather than the valency in terms of hydrogen equivalents, which gives the measure of the overall ability to combine. An overall glance at the complex metal salts known at present shows that the coordination number is fairly varied among the various types; it is very frequently 6 or 4, sometimes 8 and, more rarely, other values.

Writing the formula graphically, according to the principle of coordination, the convention is usually adopted of enclosing the central element and the units associated with it in square brackets which thus contain all the atoms involved in the co-ordination complex or internal sphere.

It may be observed here that this coordination principle supplements rather than confutes the older concepts of valency and was able to receive new improvements and new light from the electron theory of materials

These last enable the three fundamental types of valency recognized at the present time by chemists to be defined:—

(1) "Electro-valency" with polar or ionizable bonds, as in the ions carrying different charges in sodium chloride Na^+ and Cl^- in ammonium chloride NH_4 and Cl^- or in hexamine-cobalt-chloride $[Co(NH_3)_6]^{3+}$ and Cl_3^{3-}.

(2) "Co-valency" with non-polar and non-ionizable bonds like those which unite the atoms of carbon in the crystal structure of diamond or of the carbon and hydrogen in methane.

(3) "Coordination links" like those between cobalt and ammonia, as in $[Co(NH_3]_6)\ Cl_3$.

These types may be examined more closely.

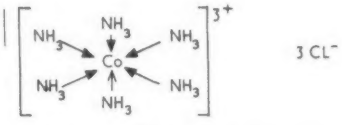
Electro-valency (polar bond)

In forming sodium chloride, the sodium gives its only outer electron (the other—internal—electrons occupy orbits which are already complete) to the chlorine which is short of just one electron to assume the configuration of argon, the inert gas following it in the periodic table (argon has, what is generally termed, a complete electronic configuration). With this surrender the sodium takes on the configuration of neon, the inert gas preceding it in the periodic table and it thus comes to acquire a more stable configuration and one with a minimum energy level among the various ones possible (maximum stability corresponds to minimum potential energy).

* *The last contribution of the present series based on a series of articles published by the Italian journal Galvanotecnica. This English version has been reproduced with the collaboration of the editor and the author of the work.*

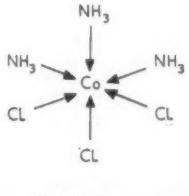
Co-valency (non-polar bond)

In the compound $[Co(NH_3)_6]Cl_3$, for example, it is observed that the molecules of ammonia are in defined positions in spcae (octahedral positions) with respect to the central atom of cobalt and the bonds are of co-valent character. Since, however, the electrons in the stable molecules of ammonia are completely paired off (or, rather, single electrons do not exist), when they combine with cobalt, they have to provide it with a doublet of their own electrons for the bond to be able to come into being. This argument is confirmed by the fact that all the molecules capable of entering the sphere of internal coordination have similar doublets and hence are capable of giving them to the coordinating atom. The structure can therefore be represented as:—



The use of the arrow, which has by now entered into common use among many writers(2), indicates the surrendered electron doublet.

A co-valent coordination link is thus a co-valent link in which both the electrons are derived from one of the two atoms in question, it being borne in mind that, once formed, there is no way of distinguishing a co-valent coordination bond from some other simple co-valent bond that may also be present in the same molecule, as in the case of:—



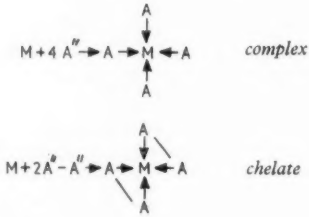
in which 3 atoms of chlorine are united *via* normal co-valent bonds. The six bonds in $Co(NH_3)_3Cl_3$ are equivalent.

The most complete explanations of these facts are provided by the quantum theories which introduce the concept of "resonance", that is to say —in the simplest possible words—of mixed bonds of the ionic-covalent or covalent-coordination types which resolve themselves, forming a harmonious whole, completely equivalent in each part.

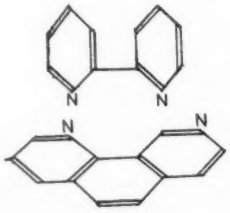
The tendency of a metal to form complexes with molecules giving up electrons can be interpreted as the tendency of the metal ions to fill the free orbits and thus approach the electron configuration of the inert gases.(3) Trivalent cobalt-for example, has 14 electrons in its two outer orbits. By acquiring 12 electrons from 6 molecules of ammonia, it acquires the stable configuration of krypton with 18 electrons in orbit M and 8 in orbit N. Although the configuration of the inert gas is not attained in every case, such a condition is, so to say, the stimulus to the quest for a more stable configuration like that resulting from the formation of the complex.

If the molecule which combines with the metal has, instead of a single donor group of doublets, two or more groups which can provide pairs of electrons in such a way that they can form with the metal one or more rings, rather than using the term "complexes", these are called "chelates", a very appropriate general term derived from the Greek word "Khili", meaning "crab".

Schematically, if M is the metal (with coordination number 4), then A is the donor group of electrons which we indicate with A″.



Some of these chelate groups have played an important part in demonstrating the stereochemical structure of some coordination compounds. For example, 2-2′ dipyridyl (I) and *o*-phenanthroline (II) provide typical examples of such groups, both used in demonstrating the octahedral structure of coordination compounds. The octahedral structure implies—as has been pointed out—that each constituent is situated at the vertices of a regular octahedron with respect to the central coordinating atom.

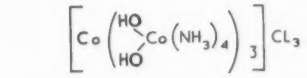


I.—Dipyridyl

II.—Phenanthroline

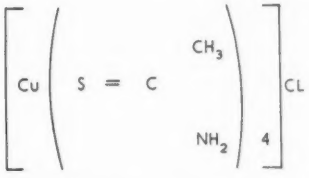
Morgan and Burstall (4) have resolved the salt of nickel, $[Ni(dipy.)_3]Cl_2.6H_2O$, which is pale red in colour, into two so-called optically active components, dextro- and laevo- (d- and l-, or right-handed and left-handed), capable of causing the plane of polarized light to rotate to the right or to the left, thus demonstrating the octahedral space arrangement of the chelate.

It is not absolutely essential for the chelate groups to be organic, since Werner (5) succeeded in demonstrating that the basic salt of cobalt dodecamino-hexol-tetra-cobalti choride (III) containing three $[(HO)_2CC(NH_3)_4]$ groups can be resolved into optically active forms.

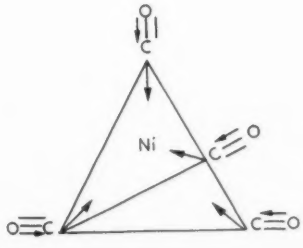
III 

Even before A. Werner noticed the coordinat on bond, the existence of tetrahedral structures in metallic elements had been demonstrated. In 1899, Pope and Peachey showed that quaternary ammonium salts of the well-known [N abcd]$^+$ X$^-$ type can be resolved into optical antipodes. The oxides of the [N abc O] amines were obtained in their optically active forms by Meisenheimer in 1908 and 1911. They and Lichtenstadt prepared the active oxides of the phosphines (P abc O). The most significant results were obtained from determinations of structures by means of X-ray analysis.

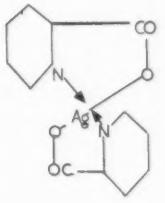
Cox, Wardlaw and Webster(6) demonstrated a tetrahedral arrangement of molecules in cuprous compounds having a coordination number 4, for example, in the well-known cyanide of potassium and copper K_3 $[Cu(CN)_4]$ and in the salt with the thio-acetamide (IV), while cupric 4-covalent derivatives (*cf.* below) have planar structures.

IV. 

Among the technically better known and more important compounds, nickel tetra-carbonyl (V)(7) can be cited.

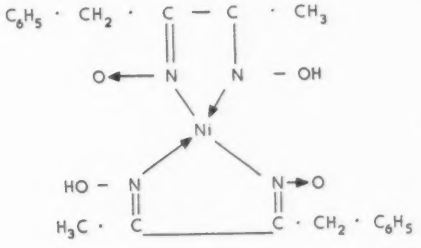
V. 

In the overall study of the tetra-covalent complexes and chelates, it was observed that copper and silver, when they manifested their fundamental univalency, exhibited tetrahedral patterns in the quadrupally coordinated compounds. In their higher states of valency, however, copper and silver exhibit a planar coordination if the coordination number is 4. Then the groups, whether complexes or chelates, all lie on one plane. By means of X-ray analysis, there has been demonstrated(8) a planar structure of this sort, for example, in bivalent copper acetyl acetonate and in the silver derivative of picolinic acid (VI).

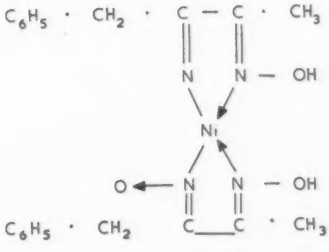


VI.

A considerable amount of work has been computed on planar compounds containing elements of group VIII of the periodic classification. In support of the planar configurations use was made of chemical evidence, in the form of the isolation of the cis- and trans- forms of the nickel and palladium salts of benzylmethylglyoxime, (VII) and (VIII).

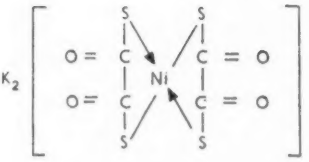


VII.



VIII.

However, X-ray analyses(9) have said the last word in demonstrating the planar structure of di-thio-oxalated complexes of nickel, palladium and platinum (IX).

IX. 

Methods of Investigating Complexes; Magnetic Susceptibility

Among the various methods used for the detection of the nature and form of a chelate or a complex, among the more important, in addition to the already mentioned optical method, which was developed by Werner, are X-ray examination of the compound (which, in the last few years, has proved itself the most reliable and effective), study of its absorption spectra,[10] study of its electrical conductivity,[11] study of the polarographic half-wave potential[12] and study of the oxidation potential of the metal.[13]

A method frequently used for detecting the formation of complexes and, in some cases, their structure, is that of taking measurements of their magnetic susceptibility.

All substances show polarization in a magnetic field and are divisible into two groups. The *diamagnetic* substances tend to move in a non-homogeneous field from the stronger to the weaker part of the field. The *paramagnetic* substances behave conversely. All atoms exhibit diamagnetism due to the influence of the applied magnetic field on the movement of the electrons. This is a function of the distribution of electron density in the atom. Some atoms and compounds, however, show besides diamagnetism a pronounced degree of paramagnetism, so that the former becomes relegated to a degree of but little importance. These are the atoms in which there are unpaired electrons (*i.e.*, not united two by two in doublets) in an incomplete level or shell. Paramagnetic susceptibility tends to be great in certain cases and depends on temperature since the orientation constituted by the permanent electronic dipoles in an applied field is countered by thermal agitation. The paired electrons of the internal shells or layers are, however, responsible for a relatively small degree of diamagnetism. The resultant moment of rotation of the electrons or, as is said in the terminology of the theory of quantum mechanics, the spin moment, is equivalent to $\sqrt{(n+2)n}$ Bohr magnetons, in which n=the number of unpaired electrons. It is then possible to obtain n *via* measurement of the magnetic susceptibility.

In the case of the transition elements from scandium to copper, when the atomic number increases by 1 unit, one (more) electron accrues in the outer shell 3d (3d refers to particular values of the quantum-mechanical parameters). The said shell consists of 5 orbits into each of which can be introduced only two electrons. The first five electrons to leave scandium in the direction of manganese each go into every one of these 5 orbits. They consequently thus remain unpaired. When the number of electrons exceeds five, the others introduce themselves in the orbits already containing one electron, but so that no orbit contains more than two. When the atomic number grows from that of manganese to that of zinc, the number of unpaired electrons drops to zero, when the shell 3d has grown complete with 10 electrons (*cf.* Table I).

In the formation of complexes with substances donating electrons, it will be understood how some orbits formerly containing unpaired electrons become complete; the total number of unpaired electrons will vary. Measurements of magnetic susceptibility, which provides such a number, will, in the last analysis, be valid for stating whether the presence of a complex can be assumed.

Furthermore, as in the more fortunate cases two types of complex, *e.g.*, planar and tetrahedral, have different numbers of unpaired electrons, the nature of such complexes can be reliably indicated by such numbers.

Appropriate in the case of Ni^{2+}, which has the electronic configuration KL $3s^2$ $3p^6$ $3d^8$, the formation of tetrahedral tetracoordinate bonds (called, however, sp^3 because formed with two electrons of the shell 4s and 6 electrons of shell 4p) and of planar bonds (accordingly called dsp^2, because formed with two electrons of shell 3d, two from shell 4s and four from shell 4p; 8 electrons, all told, hence 4 doublets: 1 doublet for each coordinated atom) allows different numbers of unpaired electrons to be present in nickel.

In the second case, in fact, there are no unpared electrons, while in the first case there are two. The complexes of planar tetracoordinated bivalent nickel are then diamagnetic, while the complexes of tetrahedral tetracoordinated are paramagnetic (from 2·6 to 3·2 Bohr magntons). It may be noted, however, that $Ni(CO)_4$, although tetrahedral, is not paramagnetic. This is a zero-valent compound of nickel, for in it the nickel has two electrons more than in the case of the derivatives of Ni^{2+}. These two electrons allow the completion of the shell 3d and, hence, determine the lack of paramagnetism. To sum up, the respective electronic structures are:—

Ni (metallic or as in Ni $(CO)_4$):—
KL $3s^2$ $3p^6$ $3d^8$ $4s^2$

Ni^{2+} (tetrahedral tetracoordinated):—
KL $3s^2$ $3p^6$ $3d^8$ $4s^2$ $4p^6$

Ni^{2+} (planar tetracoordinated):—
KL $3s^2$ $3p^6$ $3d^{10}$ $4s^2$ $4p^4$

Table I.

Element	Atomic Number	Shells and Levels									
		K	L		M			N			
		1s	2s	2 p	3s	3p	3d	4s	4p	4d	4f
Argon	18	2	2	6	2	6					
Potassium ...	19	2	2	6	2	6		1			
Calcium ...	20	2	2	6	2	6		2			
Scandium ...	21	2	2	6	2	6	1	2			
Titanium ...	22	2	2	6	2	6	2	2			
Vanadium ...	23	2	2	6	2	6	3	2			
Chromium ...	24	1	2	6	2	6	5	1			
Manganese ...	25	2	2	6	2	6	5	2			
Iron	26	2	2	6	2	6	6	2			
Cobalt ...	27	2	2	6	2	6	7	2			
Nickel ...	28	2	2	6	2	6	8	2			
Copper ...	29	2	2	6	2	6	10	1			
Zinc	30	2	2	6	2	6	10	2			

There exist, in addition to the magnetic method, other methods, some of which can, however, give qualitative indications. For example, examination of the various chemical properties of the metal, when in the form of a complex, by comparison with the normal ion. Thus precipitation of calcium ions in the form of $CaCO_3$ does not occur if these are combined with a reagent of the type of ethylene-diamino-tetra-acetic acid. This indicates that the concentration of these Ca^{2+} ions is extremely low, so low, in fact, as not to attain the solubility product of calcium carbonate.

Proof of the existence and of the structure of complexes which are stable only in solution becomes, indeed, considerably more difficult and complicated than dealing with the more stable coordination compounds which can be isolated in some way or other in the solid state.

Use can be made here of changes of colour, rotation of the plane of polarized light, lowering of the freezing point, surface tension, density, or rate of diffusion. Polarographic studies become very useful in such cases but the problem is always complicated.

Such properties of chelates or complexes are mainly determined by the nature of the organic chelating agent, by the dimensions of its molecule, by the number of rings and possible interactions of resonance which can have a stabilizing influence on a coordination compound.[14] Other factors having influence on its stability include the nature of the central metallic ion, the factors governing the relative tendencies to combine with a certain donor of doublets consisting basically of the ionic forces for which the metallic ion itself with its charge is responsible and the radius and its tendencies to form covalent bonds with the chelating or complexing groups. All this, together with the entropy and steric factors which govern these processes, makes it extremely difficult to interpret the mode of formation of coordination compounds in simple terms. It can be stated, however, that their general properties, so far as their chemico-physical behaviour is concerned, depend in the main on the electronic structures of such complexes and, even then, any quantitative explanation of these phenomena bristles with problems, which, for the most part, have still not been resolved, even by the most advanced theories of quantum mechanics.

Complexes and Bright Nickel Plating

It is necessary to examine in some detail the substantial difference in electro-chemical character exhibited by a chelated or complex ion when compared with the simple or hydrated ion which is generally found in a normal electrolyte. This will further the examination of those particular cathode phenomena which are considered to be the most important and which are still to a great degree obscure from the scientific point of view of the mechanisms involved in bright nickel plating. Indeed these processes[15] continue to take place to a large extent in the presence of organic substances which, in respect of the nickel ions in a simple Watts bath, behave very differently from other simple molecules or ions.

Considering a metal M in equilibrium with its ions in solution:—

$$M \rightleftharpoons M^{n+} + ne \quad \ldots \quad \ldots \quad (1)$$

in which M represents the (crystalline) metal, M^{n+} the metal ions in solution and n represents the number of electrons transferred to the electrode by each atom of metal M which ionises or, conversely, the number of electrons which have to be provided from the cathode and given to the metal ion so that this last may be deposited in the crystalline state. The reaction from left to right expresses the oxidation of the metal from a lower to a higher valency and the electrode, corresponding to this reaction, can be put in the form:—

$$M/Ma^{n+} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

in which a expresses the activity of the metallic ions in solution. The oxidation potential of the electrode is expressed by the familiar Nernst equation, in which the activity of the solid metal is taken as the unit value:—

$$E = E^\circ - \frac{RT}{nF} \log a, \qquad (3)$$

that is to say, at 20° C

$$E = E^\circ - \frac{0{\cdot}059}{n} \log m\gamma$$

in which

a = activity.

m = molar concentration of the metallic ion.

γ = coefficient of activity.

E = potential of the metal in contact with a solution of its ions to activity a (with reference to the hydrogen electrode which is made equal to zero).

E°=constant which is equal to E if a=1 and hence expresses the potential of the metal in contact with a solution with unit activity of its ions.

The potential E is a measure of the tendency of the reaction (1) to proceed towards the right (hence of the metal to pass into solution). If a decreases, E increases according to (3) and the tendency of the metal to oxidize increases accordingly.

The electrode potentials are usually compared with the potential of the couple:—

Pt/He gas, 1 atmosphere/H^+ (a=1), having

$$E = E° - 0{\cdot}059 \log \varepsilon_{H^+} \qquad (4)$$

which is assumed to be equal to zero when $\varepsilon_{H^+}=1$. Hence, the potential of a metallic couple (2) is definitely a measure of the tendency of the reaction (1) to proceed to the right, if confronted with reaction (4). When, also, the metallic ions are present in unit activity E=E° and the potential of a cell can be expressed as

$$E° = \frac{0{\cdot}059}{n} \log K \text{ (at } 20° \text{ C)} \qquad (5)$$

in which K is the constant of thermodynamic equilibrium for the equation of the cell, E° is called the "standard oxidation potential" of the metal M[16].

The formation of a chelate or of a metal complex is accompanied by a diminution of the ion activity of the metal and, hence, by an increase of its oxidation potential.

In the presence of chelating or complex-forming substances, electrolytic reduction of the metal ion to metal takes place at relatively high potentials, the metal thus arriving, as it were, stabilized in its electronic structure. Sometimes this potential is also raised in a fairly sensitive manner. For example, many metals which form strong chelates with dimethylglyoxime, like copper, dissolve in aqueous or alcoholic solutions of these reagents with evolution of hydrogen, even if the metal shows little or no tendency to displace the hydrogen from water or from dilute acids[17]. The action of concentrated acids on many metals is partially facilitated by the formation of complexes with the anions of the acid.

The effect of the formation of complexes in the stabilization of the bivalent state of mercury is reflected in the oxidation potentials Hg/Hg^{2+} calculated by Latimer[18], with the following data by Sherrill[19] deducible from the formula:—

$$K = \frac{(Hg\,X_4^{2-})}{(Hg^{2+})\,(X^{-1})^4}$$

and which makes it possible to calculate the dissociation constant K of the complex, note being taken of the concentrations of mercury and of the complex-forming anion X (CN^-, I^-, Br^- or Cl^-). With K given, E° can be calculated by means of (5).

Investigations of this type were made recently by Roth and Leidheiser,[10] whose theory regarding the effects of substances capable of providing electron doublets on nickel-plating have already been mentioned.[21]

From their work a curve (Fig. 1) illustrating the increase in cathode potential (in mV) as the result of adding an organic agent in progressively greater concentrations is shown.

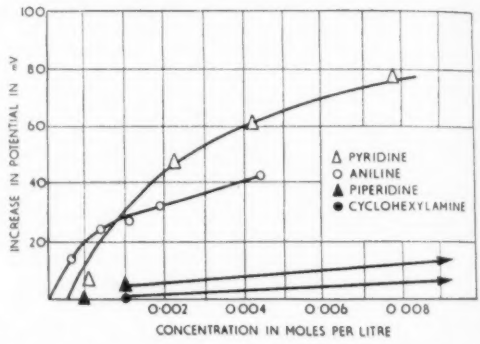


Fig. 1.—Curves showing increase in cathode potential as a result of adding organic agents

The increase in potential is given by the difference in cathode potential in the presence and absence of the organic compound. It is noteworthy that the increase in potential brought about by organic substances which facilitates, at the same time, bright nickel to be deposited, usually falls by between 20 and 50 mV by comparison with the unmodified Watts bath.

The increase in potential in the presence of organic compounds was ascribed by Hackermann and Sudbury[22] to their direct adsorption. It is now an undoubted fact that such adsorption is effected at the surface, as Roth and Leidheser had occasion to confirm with Raney nickel which was particularly active. It is not logical, however, to deduce directly that this alone is responsible for the variation of all the electrochemical phenomena inherent in nickel ions, the more so as not all substances adsorbed by Raney nickel are able to provide bright deposits in electrolytic baths of this metal.

The standard oxidation potential always becomes greater (or, rather, the tendency of the metal to pass into solution increases) hand in hand with the power of the anion to form complexes.

Recently, Kleinberg[23] has made clear the part played by the formation of complexes in stabilizing unusual states of oxidation in metal. For example, most known compounds of Ag^{2+} and Cu^{3+} are complexes or chelates.[24] Bailor[25] has suggested that the state of oxidation of cobalt in azo- and

azomethine dyes can depend on the number of chelating groups and on the number of replaceable hydrogen atoms in the molecule of the dyestuff.

Bezier[26] measured the potentials of the Fe^{2+}/Fe^{3+} couple under conditions in which the ferric ion was in equilibrium with a complexing or chelating agent. He found that the oxidation potential was enormously increased but he did not find it possible to express his results quantitatively in terms of the equilibria in play. In general, the data in the literature indicate a considerable increase in the oxidation potential, as a result of the formation of complexes. For example, in the case of copper, $E°=-0{\cdot}167$ V through the oxidizing reaction $Cu^{1+} \longrightarrow Cu^{2+}+e$, while $E°=+0{\cdot}58$ V through the reaction $2\,HN_3+Cu(NH_3)_2^{+} \longrightarrow Cu(NH_3)_4^{2+}+e$.

It is known that an ion brings about a negative contribution of entropy, due to the restriction of the grades of liberty of the molecules of the solvent in the vicinity of the said ion and that this effect is greater the higher its charge. An increase in the charge of the ion involves, however, an unfavourable drop in entropy. When a metal in an ionic state of simple solvation becomes oxidized, the contribution of entropy (due solely to this factor) diminishes. On the other hand, an increase in valency of the metal ion, when this exists in a negative anion, as $Ni(CN)_4^{2-}$ could be, implies a diminution in the charge of the ion and a corresponding increase in entropy. The entropy factor thus favours the form of the metal with the higher valency in the form of a negative complex much more than in the form of a solvated positive ion. The region of stabilization of a state of higher valency by a neutral donor of doublets, as ammonia could be (neutral in respect of the transported charge), is not immediately apparent, in terms of entropy. It is probable, however, that some influence is exerted by the increased size of the ion and the diminished interaction of the ion itself with the solvent (something which always tends to cause the entropy to diminish).

In addition, the relative oxidation potentials of substituted o-phenanthroline provide an illustration of the effect of the donating ability of doublets of the chelating agent on the potential itself. In general, its increase depends on the number of doublets which the complex-forming agent can provide. Accordingly, the existence of captor groups of electrons in the chelating or complex-forming compound does not favour a rise of potential.

Comparison between the potentials of the ferrocyanide/ferricyanide and ferro-o-phenanthroline/ferri-o-phenanthroline couples would seem to constitute a violation of the principle emphasized above. In fact, both the couples involve only co-valent structures and it might have been expected that the oxidation potentials in both would have turned out to be less than those of the hydrated ions, by virtue of the fact that the ferrous form in the complexes has the electronic structure of inert gas which is relatively stable and that, as already observed, all elements (transition elements or not) have this tendency. In spite of this, the oxidation potentials are higher in the hydrocyanic complexes and lower in the o-phenanthrolenic complexes. This apparent anomaly is soon banished if it is remembered that hydrocyanic complexes are negatively charged (CN^- ions) and hence are subject to the considerable effect of entropy, mentioned above, while the o-phenanthrolenic complexes are neutral end, hence, can only involve contributions of antropy which are on the low side. Nevertheless, in the process:

$Fe^{2+} \longrightarrow Fe^{3+}+e$,

the potential $E°=-0{\cdot}771$ V;

while by the process $Fe(CN)_6^{4-} \longrightarrow Fe(CN)_6^{3-}+e$

the potential $E°=-0{\cdot}36$ V;

and by the process $Fe(o\text{-phenan.})_3^{2+} \longrightarrow Fe(o\text{-phenan.})_3^{3+}+e$

the potential $E°=1{\cdot}14$ V.

Thus, in the hydrocyanic complexes, the potential is influenced by two opposing effects: the entropy effect which tends to raise it, and the effect of electronic doubleting which tends to lower it. It is the first which prevails. In o-phenanthroline it is the second which prevails and the potential accordingly drops in comparison with the hydrated ions.

The concept of the influence of the formation of chelates or complexes on oxidation potentials or, inversely, of electrodeposition of metals seems, in the majority of cases, to have provided the most logical and convincing results. In any event, increasingly more abundant experimental evidence is accruing with the result that this concept may extend its utility to wider fields.

There is still another way in which complexes, particularly chelates, can affect deposition potentials. If an ion with a relatively inert structure comes to be surrounded with compounds like phthalo-cyanine or porfirine, the rate of the oxy-reducing reactions becomes greatly slowed down. All this reveals the enormous importance of the phenomena of complexing or chelating in the field of metal deposition, having, as they do, a direct influence in varying the electronic and, hence, the electrochemical properties of the ions in solution.

In the case of bright nickel plating, the factors which lead to this phenomenon must be similar, *i.e.*, formation of cathodic film of brightener by adsorption, migration of the film, etc., but what mainly influences and determines the favourable course of the electrodeposition is undoubtedly the ability of this film of brightener at the cathode to form complex salts with nickel. This ability is also

(*Continued in page* 127)

FINISHING POST

A SELECTION OF READERS' VIEWS COMMENTS AND QUERIES ON METAL FINISHING SUBJECTS . . . . .

Advice on all aspects of metal finishing practice is offered on these pages, and while every care is taken to ensure the accuracy of information supplied no responsibility can be accepted for any loss which may arise in respect of any errors or omissions.

Abrasion Testing

Dear Sir,

I was pleasantly surprised to read the letter from Mr. Davey of Funditor Ltd. in your February issue and to learn that there is a representative of Taber Instrument Corporation in this country. Recently, in June, 1956, we purchased new wheels from the U.S.A. and the American firm did not mention the existence of their agents in this country. Had we known, it would have saved us a lot of inconvenience.

We obtained our Taber Abraser, model E-4010, from The Taber Instrument Corporation in March, 1954. I do not think that it could have been obsolete for many years or that a scientific instrument should have become obsolete so quickly otherwise it casts a shadow of doubt on the value of the instrument.

The working life of resilient Calibrase wheels is restricted to one year by the manufacturers, owing to gradual deterioration of the rubber matrix. During the work carried out on the abrasion resistance of vitreous enamels three sets of Calibrase wheels were used. With some interchange of wheels between pairs in order to prolong their usefulness some 220,000 wear cycles were obtained. Since the minimum number of wear cycles required to test a typical vitreous enamel surface is 5,000 wear cycles, one set of wheels is sufficient to test only 15 enamel samples. I suggest that this is a short working life.

With reference to the diamond refacing procedure suggested, the wheels do not need trueing after every test. The carborundum disc refacing is used to clear the surface of the wheels of any debris likely to clog the surface and introduce unknown factors into the test. The diamond refacing must also remove more of the abrading material surface and further reduce the effective usefulness of the wheels.

Yours faithfully,
B. K. NIKLEWSKI.

Managing Director,
Main Enamel Manufacturing Co. Ltd.,
London, N.18.

Electroplate Performance

Dear Sir,

I wonder if the electro-platers have noticed the variety of colours now to be seen on their work on motor cars.

If they have, it should bring home to them the very poor protection some of their plating affords, and they should hang their heads until the shining pristine brightness is once more relied upon to embellish and protect the base metals below, and not need the addition of a coloured lacquer.

It can be done. Once I had a chromium-plated copper water-heater in use in the laboratory for about eight years, and the inside where the gas flame touched the metal failed before the bright chromium plate had lost its shine, in spite of the fumes of the laboratory. However, I am forced to add it was not plated in this country.

Yours faithfully,
DOUGLAS M. BLOOMER.

Managing Director,
Ernest A. Lewis and Co. Ltd.,
Birmingham 4.

Non-electrodeposits

3273. We are faced with the problem of producing a really effective corrosion resistant coating on a number of small components for use in electrical equipment under somewhat severe service conditions. Unfortunately electrodeposited coatings, although quite satisfactory from the corrosion resistance point of view, are not acceptable, as we have found in a number of instances that the components have acquired a small amount of permanent magnetism during the process. Similarly we have not been able to make use of hot dipping processes as some properties of the component are adversely affected by the temperatures at which these processes are carried out.

It would appear that the solution to this rather specialized problem might well be found by the application of one of two recently-developed coating processes. The Kanigen process deposits a coating of nickel by chemical reduction without the use of an electric current. This coating has excellent corrosion-resistant properties and its thickness can be controlled to very fine limits. Alternatively a process which lends itself particularly to the coating of large numbers of small components is the Peen-plating process recently introduced to this country. In this case coatings of the softer metals, e.g., zinc, tin and cadmium, are produced on the articles by a mechanical tumbling process in a barrel containing carefully selected media and metal powders. These coatings also show excellent corrosion resistance and are capable of exact control. The enquirer has been supplied with the names of the companies operating these processes in this country, from whom full details can be obtained.

MODERN PAINTS *and* Their Application

By E. E. COKER*

(A paper presented to the North-West Area Branch of the Institute of Sheet Metal Engineering)

PAINTS and their methods of application are so interrelated that they cannot be considered independently, and to obtain a high-quality finish, the finishing procedure used, *e.g.*, degreasing, pretreating, corrosion inhibiting, priming, etc., will not be cheap.

Having decided to use a paint finish, a manufacturer then has to decide which process to use and advice on this and the type of paint to be used can be obtained from paint suppliers. There are many reasons for using paint, for example, to prevent corrosion, to make articles look more attractive than in their natural state, or as a protection against a particularly corrosive environment. Each reason for painting will call for a different processing method and type of paint. This, however, is the theoretical approach usually possible only on a new venture; in other cases where existing plant has to be used or where cost has to be considered a compromise is often required.

Technical advances made in recent years have taken the element of chance from the quality of paint. Whereas linseed oil used to be the basis of nearly all paints and the paint properties varied according to the oil used, today synthetic resins have largely replaced straight oils and the paint chemist can control his raw materials instead of being dependent on the vagaries of nature.

There are too many types of paint for use on sheet and strip metal to discuss them all individually, *e.g.*, primers, fillers, undercoats, with finishes that can be matt, semi-matt or gloss, and which are either air-drying, convection-oven stoving or radiant-heat curing. Therefore, it is intended to concentrate on those that are widely used, or generally not well understood.

Primers

It is true that if a good water-resistant stove enamel is used it will adhere well to properly degreased metal and the protection obtained will be satisfactory. However, few stove enamels are impervious to moisture and this is the gap that anti-corrosive primers fill.

The solubility in water of certain polar pigments such as zinc chromate provides cathodic protection, and although research on corrosion-inhibiting pigments is always being carried out, zinc chromate is the most widely used in conventional primers, with the exception of red lead.

Etching primers, which afford a high degree of corrosion inhibition, are finding an increased use in industry. They are based on special types of vinyl resin pigmented with zinc-tetroxy chromate and usually need to be mixed with an acidic component. Although this is referred to generally as a catalyst, it is not strictly correct in view of the definition of a catalyst as a substance that promotes chemical change without being chemically concerned itself in the change. There is a speedy reaction between the acid component and the base primer, and because of this the mixture should be used within a certain period otherwise gelation takes place. The main characteristics of etching primers are:—

(1) They will adhere to a large number of surfaces, including galvanized iron, brass, cadmium and other plated surfaces, as well as peculiar surfaces like plastics.

(2) Rapid speed of drying which will allow overcoating in 30 min. at ordinary temperatures or much less at elevated temperatures.

(3) Good corrosion resistance.

(4) Their virtual replacement of metal pretreatment as an independent operation.

The primer is available in a ready-for-use state which is essentially the same as the two-solution type, but on particularly difficult surfaces the two-solution version is preferable. Also, if low-temperature air drying is used, the water sensitivity of the applied film is rather less. Etch primers have a much higher sensitivity to moisture than usual and metal should not be left in the primer for an undue length of time. If there is a risk of outside condensation, as in shipyards and certain aircraft factories, then careful consideration should be given to their use.

Another comparatively new type of primer is the zinc-rich primer which provides an anodic coating giving cathodic protection to steel. These primers are almost half-way between galvanizing and painting, having a metallic zinc content well over 90 per cent.

Nitro cellulose-type primers are not generally advocated unless production exigencies compel. They have inferior adhesion and durability as compared with synthetic-based primers.

* Cellon Ltd

Fillers

The same remarks do not apply to fillers, as they are in contact with the organic coating on top and separated from the inorganic metallic substrate by primer. This type of paint should not be judged solely upon the thickness deposit obtained, but also on its effect on the general physical character of the laminated film. A very thick film can be due to the filler being heavily loaded with pigment, and this film will be very absorbent; succeeding coats of undercoat and finish will sink right in and the final product will look as if it needs an extra coat of paint. If insufficient pigment is present the filler will not sand properly nor have the requisite film properties, and succeeding coats will not, or should not, sink in.

The aim of the paint manufacturer is to strike a "happy medium" and some success has been achieved recently. High-sheen primer fillers are available based on specially selected synthetic resins and inert inorganic pigment dispersed in such a manner as to reduce to a minimum the porosity of the film.

Finishes

In the field of finishes the position is very different from the immediate post-war period due to advances with both synthetic resins and solvents. The most outstanding development under the heading "synthetic" is the epoxy, "Epikote", or epichlorhydrin diphenylolpropane condensation derivative.

Epoxy resins are expensive, *i.e.*, approaching double the price of conventional finishes, but the degree of resistance shown is much higher than was possible with orthodox phenol melamine urea, etc., and thus epoxy finishes are of interest to manufacturers of articles which come into contact with chemicals, *e.g.*, washing machines and refrigerators. A number of different types of epoxy paints is available, *e.g.*, air-drying when catalyzed, low-bake and medium-high-bake types. If maximum resistance is required, the most expensive type epoxy resin must be used, the curing temperature being 350° to 360° F. for 45 minutes. If a lower resistance is satisfactory cheaper-type epoxy resins may be used; these are stoved for 30 minutes at 250° to 260° F. If stoving cannot be carried out the cold-catalyzed type will give a very tough and resistant finish. The catalyst is not acidic and again the term is wrongly used because the resinous catalyst does combine with the other resins to form complex polymers. An air-drying non-catalyzed type epoxy finish is also available. As a result of accelerated weathering tests it is thought that a high degree of durability should be obtained with these resins.

An exceptional property of epoxide resins is their ability to adhere to metal and to give a high degree of protection without the necessity of using a primer. The electrical resistance of an epoxy film is also high and this probably has a bearing on its adhesion characteristics, especially as adhesion forces at interfaces can be considered to be electrical in character.

Another resistant finish which may be applied direct to metal is vinyl enamel, which is based on vinyl copolymers and has certain advantages over epoxy finishes for particular uses. Collapsible tubes, *e.g.*, of aluminium or tin, or tin-coated lead, are roller coated with vinyl enamel to provide a finish resistant to toothpaste, various food-stuffs and detergents, at an economic price.

Another use of vinyl enamel, although to a lesser extent than epoxy enamels, is as an alternative to vitreous enamel for use on sink units, etc. Although not so resistant to cutting or abrasion as vitreous enamel, the tougher, less brittle coating is virtually non-chipping. Vinyl finishes are air drying in about 30 minutes but to obtain maximum adhesion and resistance they should be stoved for about 30 minutes at 230° to 250° F.

A widely used finish is the so-called "hammer finish" of which there are three types in general use, *viz.*: (1) the two-component type sprayed with special equipment to cause the two components to meet on the article (the Dimenso process); (2) a finish which forms its "hammer" pattern due to its content of silicone surface-active agent which compels the spray-applied film to form up in ridges leaving a pock-marked appearance as the "hammer"; and (3) a hammer finish which may be either air dried or stoved and which gives a hammer pattern similar to the two-component type. Careful blending of volatile constituents with special synthetic resins causes the surface disruption in this case.

Silicones are used in engineering for special-type lubricants and mould release agents, and these properties can be attributed to the surface tension effect displayed by silicones. Mere traces of silicone fluid have profound effects on surfaces in juxtaposition, a typical example being their use as anti-foaming agents. In processes where oils are reacted at elevated temperature frothing is inevitable, and in the past this has seriously hampered production. By the use of as little as one part per million, *i.e.*, less than 5 cc. of silicone per 1,000 gallons, frothing is prevented. The "potency" of silicones needs careful control if trouble is to be avoided in the paint shop. For example, if traces of silicone are present on a surface to be painted a disruptive pocked finish is obtained and it is virtually impossible to remove this effect without stripping and removing the surface contamination. An example of this, known to the author, took place in a works manufacturing radio cabinets, where it was found that the use of a silicone polish in the packing department was causing

blistering of lacquer in the spray shop over 30 yards away. Rejects increased from the normal 3 per cent. to 80 per cent.

Silicone-based paints are available for use where very high temperatures are to be encountered, *e.g.*, on flue stacks or on high-temperature vessels such as super-heated-steam blow-down tanks. This type of paint is expensive, ranging from £5 to £12 per gallon, and its use is therefore restricted. The same comments apply to high-temperature-resistant paints based on butyl titanate.

Styrenated alkyds also offer excellent drying characteristics, and although they do not have quite the same high order of durability as alkyd enamels, they are widely used. The incorporation of styrene into the alkyd means a combination of drying methods, the oxidation and polymerization of the alkyd being supplemented by the evaporational drying of the styrene. For this reason the dried film is more readily attacked by solvents than a straight alkyd enamel and care needs to be exercised in the choice of succeeding coats.

Special Paints

Metallic stopper is a paste-like product used directly on to metal to fill up any depressions in the surface where panel beating or rollers cannot be used, for example, on fabricated articles. The stopper has a synthetic resin base and is extremely rapid drying. When set, the stopper may be smoothed off flush with the metal surface leaving a brightly polished metallic surface. It is difficult to detect any difference in hardness between the stopper and the base metal and, in general, the patching up may be regarded as permanent. This type of stopper is used extensively in the repair of motor-car bodies.

In contrast, strippable coatings are removed easily from a surface; they are used for the protection of metal surfaces either during storage, or from damage during processing, for example, during pressing.

The chemical milling process, which is now used in the aircraft industry, involves the application (by silk screen) of a resist which protects the metal from the action of the etching solution employed. A similar process is used for the production of printed circuits, which are being used increasingly as an alternative to the repetition wiring of small circuits. The process consists of reproducing the diagram of the circuit on to orthodox silk screen. This is carried out either by cut stencils or by the photo stencil technique and a special screening resist is used for printing on to plastic/copper-foil laminate. When dry the unwanted copper foil is etched away by an acid-bath immersion and the printed circuit is left in copper laminated to a plastic base.

Recent Developments in Paint Application

The object of all methods of application is to spread a thin, even film of liquid over a solid surface. Brush application is usually only used industrially in cases where no alternative method may be used. This is not because brushing produces unsatisfactory results but because it is costly and slow. In some fields it is still used although spray equipment could be used. For example, coach painting and ship painting, the reason being that brush application is very efficient in working paints into a surface.

Attempts have been made to utilize this characteristic in mechanical brushing where the shape of articles to be painted is suitable. Attempts to speed up the brushing process have been made by the invention of a special paint brush, which ensures a constant feed of paint through the stock of the brush to the bristles, thus eliminating the time wasted in dipping the bristles into the paint.

A different method of paint application which has been known for a very long time, but which is only recently being explored and exploited on any scale, is roller coating. This method is simple, rapid and cheap for bulk production, but its use is limited. Like a printing machine a roller coater has its ink or paint supplied to an impression roller through the medium of a fountain consisting of either two contra-rotating rollers, or a roller with a "doctor" blade, the amount of paint applied depending upon the adjustment of the fountain. It is important that the surfaces to be painted are perfectly flat because the resilience of the synthetic rubber normally used on the impression roller is not great. Specially formulated paints have to be used on roller-coating machines if optimum results are to be achieved, the types available ranging from clear and pigmented nitro-cellulose lacquers, to air-drying and stoving synthetics.

Flow-coating consists essentially of conducting paint through a system of pipes in order to deliver it at strategic points where it will flow by gravity and coat the entire article. Flow coating is a useful method of painting very large articles which require to be painted on all surfaces and which cannot, by their sheer size, be painted by dipping. Paints for flow coatings must have the property of wetting metal surfaces readily, coupled with a high degree of stability or freedom from change of viscosity.

The requirements of paints for application by dipping, possibly the cheapest method of all for paint application, are similar. The process is so well known as to call for very little comment, but there are three distinct types of dipping: (1) control dipping at slow rate of extraction, *e.g.*, 1 in. per min., such as is widely used for brush handles and similar articles; (2) conveyorized dipping, mainly used on large industrial plants for coating large or

(*Continued in page* 126)

CEBELCOR COMMENTARY

CEBELCOR has lost a particularly eminent, active and zealous supporter by the recent death of Mons. Leon Devienne, director of production at the Société Interbrabant. Mons. Devienne was always keenly interested in the work of Cebelcor, it was on his initiative that the Commission for descaling processes was created in 1950. During the past six years Mons. Devienne never grudged to Cebelcor the generous support of his authority, of his untiring activity, or of his considerable learning. His loss will be deeply felt by all those who had come to appreciate his exceptional qualities in the course of a long collaboration.

Forthcoming Anglo-Belgian Meeting

On April 1 and 2 next, a joint meeting has been arranged by Cebelcor in collaboration with the Corrosion Group of the Society of Chemical Industry and other Belgian organizations concerned with corrosion. The provisional programme for this meeting, which will be held at the headquarters of Fabrimetal, 21 rue des Drapiers, Brussels, has been drawn up as follows:

Monday, April 1

Opening of meeting followed by technical papers.

"The Corrosion Group of the Society of Chemical Industrty its Activity and Organization" by T. P. Hoar, Ph.D., B.Sc., F.R.I.C., F.I.M., and E. L. Streatfield, B.Sc., F.R.I.C., M.I.Chem.E.

"Stress Corrosion Cracking" by T. P. Hoar.

"Research in Progress at Cebedeau on the Corrosion of Metals by Domestic and Industrial Supply Waters" by Prof. E. Leclerc.

"The Role of Corrosion Inhibitors in Water Treatment" by E. L. Streatfield.

"Problems Involved in the Cathodic Protection of Bare Buried Pipelines" by K. A. Spencer, B.Sc.(Techn.), and M. G. B. Nolan, A.M.I.Mech.E.

Tuesday, April 2

"Work of the Corrosion Commission of the Belgian Association for Materials Testing" by M. van Rysselberge, Dr.Sc., and C. Fontana, Ir.A.I.Gx.

"Report on the Work of Cebelcor" by M. Pourbaix, Dr.Ir., N. de Zoubox, Ing.techn., J. Laureys, Ir., J. van Leugenhaghe, Ir., and J. Van Muylder, Lc.Sc.

"Corrosion Control in Industry" by J. Strebelle, Ir.

The presentation of these papers will be followed by a general discussion and on the following two days an opportunity will be provided for visits to be paid to the various laboratories investigating corrosion under the aegis of the organizations sponsoring the meeting.

Proceedings at the meeting will be in either French or English and a cordial invitation to be present is extended to all those interested in the subjects under discussion. However, as accommodation is limited those wishing to attend are requested to communicate as soon as possible with Dr. M. Pourbaix, director of Cebelcor, 21 rue des Drapiers, Brussels, Belgium.

*A Report of the Activities of the Belgian Corrosion Research Centre**

Scientific and Technical Activities

In the field of study of the electrochemical behaviour of metals and metaloids a further paper (RT.41) has been published on the Electrochemical Behaviour of Chromium. Several other studies are in the course of publication relating particularly to aluminium, chlorine, zirconium, antimony, and the passivating action of chromates, molybdates, tungstates, and vanadates. Lectures dealing with these studies were delivered by Mons. Pourbaix in Paris during November during the first European Congress on Corrosion, and in Brussels later in the same month during the course of a Cebelcor discussion meeting.

A further contribution to the funds of Cebelcor for the continuation of its researches has been made by I.R.S.I.A., while several technical reports have been translated into English and published in the proceedings of the seventh and eighth meetings C.I.T.C.E. (Lindau 1955 and Madrid 1956).

Commission Activity

Technical Commission CT.4 on Cathodic Protection has received from I.R.S.I.A. a further subsidy for carrying out its researches which deal principally with the behaviour of reactive zinc and magnesium anodes and with the cathodic protection of structures in steel and in lead. A report on the work of the Commission during the past year will shortly be circulated among the members of the Commission.

Technical Commission CT.12 on De-scaling Processes is shortly to circulate among its members a report on its work during 1956. This work has chiefly constituted a study of electrical and magnetic treatments and the use of metaphosphates.

Since the last report a number of technical enquiries have been dealt with by Cebelcor, relating chiefly to corrosion of water and steam circulating systems and corrosion in the chemical industry.

COATING BY THERMAL DIFFUSION*

Chromizing Practice at the Works of the Metal-Gas Co. Ltd.

CONSCIOUSNESS of the current demand for treatments which will protect the surface of steel articles against corrosion, heat and wear, and so extend their useful life, is exemplified by the commercial development of the patented chromizing process by Metal Gas Co. Ltd.

Although the primary products of the Colville Group cover a wide range from ordinary mild steel to the highly-alloyed special steels produced by The Clyde Alloy Steel Co. Ltd., nevertheless there is a gap, both in cost and in ease of fabrication, between the low-alloy and the high-alloy steels. Chromizing, together with the galvanizing treatment carried out by Smith and McLean Ltd., and the development of Colclad stainless clad steel, is designed to fill this gap.

The Metal Gas Co. Ltd., was formed to investigate and develop processes for the formation of alloys by the diffusion of one metal into the surface layers of another metal.† Its continuous programme of research, both fundamental and applied, has resulted in the development of an increasing market for chromizing and to cope with this a full-scale production plant has been installed at Mossend Works, Bellshill.

Mechanism of Chromizing

Chromizing is a process for converting a zone at the surface of ordinary steel into a corrosion-, heat-, and wear-resisting alloy, the transformation being effected by the impregnation of the surface with chromium by chemical reactions taking place at a high temperature. In many applications where expensive highly alloyed steels are normally used, considerable savings can be effected by replacing them with ordinary steel whose surface is protected by a chromizing treatment.

The essential mechanism of chromizing is that of the relatively fast rate of diffusion or migration of one metal or element into another when they are in contact at a high temperature. Typical of such a mechanism are processes in which steel is heated in zinc or aluminium dust so that its surface is enriched in the respective metal. A similar method for enriching the surface of steel with chromium demands that the steel be heated to a temperature which is too high to be practicable.

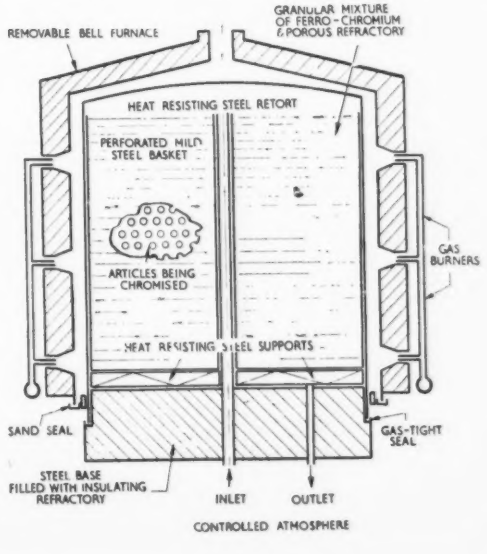
In the chromizing process, however, to overcome this difficulty, chromium is brought to the steel surface in the form of a vaporized compound of chromium, chromous chloride ($CrCl_2$), in which the chromium is in a highly reactive state. Use is made of two chemical reactions which can be expressed by the following equations:—

$$Fe + Cr\,Cl_2 = Fe\,Cl_2 + Cr \quad (1)$$

$$Cr\,Cl_2 + H_2 = Cr + 2\,H\,Cl \quad (2)$$

At temperatures of the order of 1,000° C, which is a practicable temperature for commercial operation, these reactions occur freely, and their effect is to introduce chromium into the molecular structure of the surface of the steel, thus providing the optimum conditions for diffusion of the deposited chromium into the steel. There is also a corresponding counter-diffusion of atoms of iron

Fig. 1.—Diagrammatic sketch of "Bell Type" chromizing furnace.



* *This description forms part of a comprehensive Technical Survey of the Colville Group of companies published by our companion journal, "Iron and Coal Trades Review".*

†British Patents Nos. 492521, 510871, 516260, 617849, 633701, 662333, and 727567.

outwards to the surface where they are replaced by further atoms of chromium by the chemical reaction expressed by equation (1). This process is continuous so long as a supply of vaporized chromous chloride is maintained at the surface of the steel.

In practice, chromizing consists in heating the articles to be treated (which must be free from grease and scale) in a controlled-atmosphere furnace, in which they are embedded in a granular mixture composed of ferro-chromium and a porous refractory material as illustrated in the diagrammatic sketch. A reducing atmosphere is maintained inside the furnace by the passage through it of a continuous stream of hydrogen. The desired compound of chromium, chromous chloride, is produced by the introduction, at a certain phase of the treatment, of anhydrous hydrogen chloride, which reacts with the ferro-chromium surrounding the articles, according to the following equation,

$$Fe\,Cr + 4\,HCl = Fe\,Cl_2 + Cr\,Cl_2 + 2\,H_2$$

At the temperature at which this reaction occurs, a preponderance of chromous chloride over ferrous chloride is formed. The function of the porous refractory, which is chemically inert, is to act as a diluent of the ferro-chromium and as a reservoir of chromous chloride, which is absorbed into its pores.

Time and temperature of treatment are fixed by the type of steel being treated, and by the depth of impregnation desired. They normally lie within the range of 4 to 12 hours at a temperature between 950 and 1,050° C.

It will be seen, therefore, that chromizing is a batch process, in which the cost of treating any particular article depends mainly on the space occupied by that article inside the treatment retort.

Properties Imparted to Steel

Practically, the cost of chromizing ranges from a few pence to several shilling per pound weight.

The properties imparted to steel by chromizing depend mainly on the composition of the metal being treated. The nature of the chromium-rich

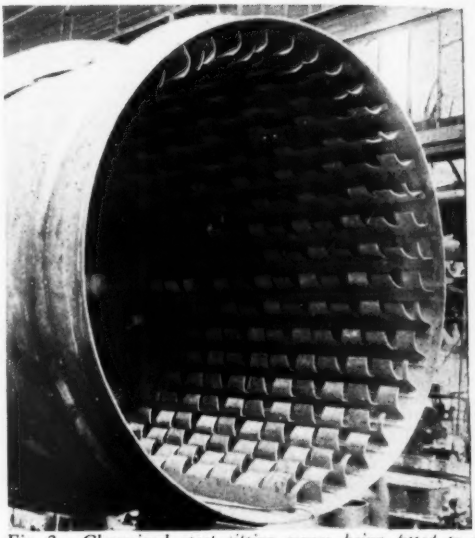


Fig. 3.—Chromized steel lifting vanes being fitted to a stainless-steel rotary drier for processing milk sugar.

zone formed at the surface of the steel varies from relatively soft, ductile, iron-chromium alloy containing approximately 50 per cent. of chromium on the outer surface, and an average of 30 per cent. of chromium throughout, to substantially pure carbides of chromium and iron which make the zone extremely hard and have an average chromium content of approximately 70 per cent. The determining factor is the amount of carbon in the steel free to combine with the deposited chromium during treatment.

On ordinary mild steel, a zone of iron-chromium alloy free of carbides can be formed only if the section of the article is thin. For certain applications it has been necessary, therefore, to devise special steel compositions when the optimum softness and ductility of the pure iron-chromium surface alloy are required. The most effective of such steels is one of low carbon content with a small amount of titanium added to combine with all the

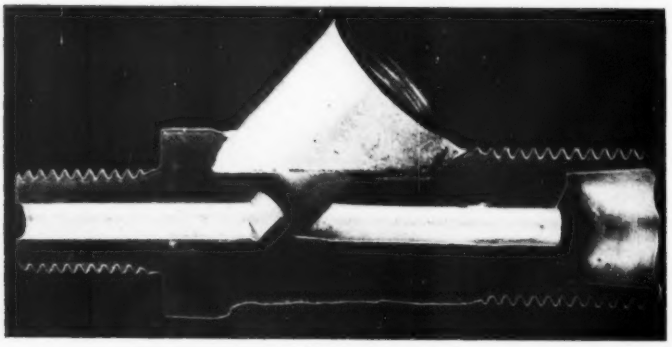


Fig. 4.—Chromized diesel-indicator valve body made in low-carbon titanium-bearing steel. Sectioned after chromizing and etched in nitric acid to show uniformity of chromizing over external and internal surfaces.

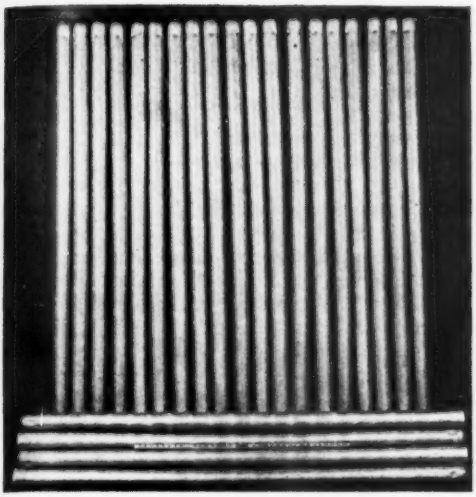


Fig. 5.—Chromized mild-steel recuperator tubes which have given over three years' service at 600° C.

carbon in the steel, and thus prevent its combination with the chromium introduced into the surface. The chromized surface produced on such a steel has a hardness of approximately 110 V.P.N., and is impregnated with chromium to a depth of the order of 0·006in. It has corrosion-resisting properties equivalent to those of 30 per cent. chromium stainless steel, and is not damaged by subsequent deformation of the article.

Where resistance to oxidation or scaling at elevated temperatures is desired, chromizing is often combined with subsequent processing with aluminium and silicon compounds. Most grades of low carbon steel treated in this way possess resistance to scaling for indefinitely long periods at temperatures up to 850° C, and for over 2,000 hours at 925° C. Experience has shown that chromizing is among the best methods of protecting ordinary steel against high-temperature oxidation. This has been borne out by independent investigators. In one such investigation into the relative effectiveness of chromizing, aluminium coating and enamelling, it was proved that "in terms of absolute resistance to oxidation, chromizing is the most effective treatment" (Sully, A. H., Brandes, E. A., and Brown, R. H., *Metallurgia*, 1954, **49**, 294).

A valuable feature of the process is that, due to the nature of the chemical exchange reaction occurring at the steel surface, and to the diffusion mechanism, there is little or no change of dimension of the treated article. When alteration does take place, it is only a fraction of the thickness of the impregnated zone, and is dependent on the extent to which the reduction reaction expressed by equation (2) occurs.

Advantages of the Process

In practice, the advantages of using chromizing are considerable. By allowing components to be designed and fabricated in inexpensive, easily-machined materials, the cost of producing them can be greatly reduced. By virtue of using only a small proportion of chromium in relation to their bulk, the difficulty of using scarce and expensive strategic alloys can be overcome. By providing an easy method of forming highly-specialized alloys, components of novel and unique properties may be produced. These advantages are exemplified by the following, typical, industrial applications of the process.

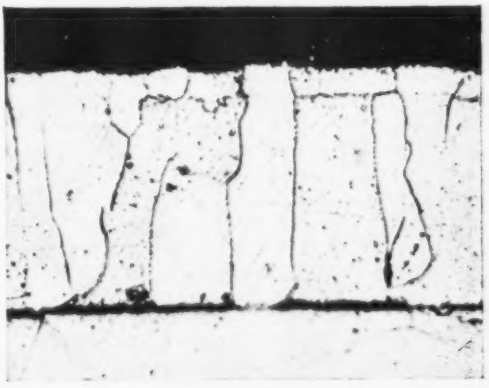
Mild-steel carburizing boxes, chromized to give maximum heat-resistance, have a life under actual working conditions of at least two thousand hours at the temperature of 925° C. Generally, boxes made from heat-resisting alloys, costing more than three times as much as the chromized boxes, have a life of four thousand hours, so that the use of chromizing represents a saving in cost of at least one-third.

Diesel indicator valves must be capable of withstanding the corrosive action of the hot diesel gases, as well as the relatively severe atmospheric corrosion often encountered. The body of the valve is of intricate form and has previously been fabricated from mild steel with special heat-resisting packings or from copper alloys subsequently electroplated. Chromized, titanium-bearing, low carbon steel bodies are now widely used in marine and land installations, and are specified by Admiralty and Ministry of Supply. Their cost is less than one quarter of that of the electro-plated bronze valves which they have replaced.

Chromized mild-steel recuperator tubes are being used in gas-fired furnaces as a substitute for

(*Continued in page* 126)

Fig. 6.—Photomicrograph of chromized zone on titanium-bearing low-carbon steel. Zone consists of columnar grains of iron-chromium alloy. (x 400.)



Coating by Thermal Diffusion

(*Continued from page* 125)

expensive heat-resisting iron or steel tubes. One set of chromized air-preheating tubes has been in constant service for over three years at 600° C with no deterioration in either performance or condition. A set of chromized gas-preheating tubes, replacing heat-resisting iron tubes, is intact after more than two years of continuous service in a steelworks, whereas within twelve months several of the heat-resisting tubes had failed.

Low-cost chromized mild steel expanded metal in increasing quantities is replacing expensive heat-resisting steel as a material for the grill frets of domestic gas-cookers. Accelerated life tests show that the chromized frets have an expected service of at least ten years at the operating temperature of 800° C.

Examples of Application

An example of the unique properties which can be produced by chromizing is its application to the electrodes of sparking plugs for internal combustion and jet engines. The electrodes must be capable of withstanding high temperature and attack by lead, sulphur and other corrosive substances, and, in addition, must be able to be welded satisfactorily to a platinum tip. It has been found that chromizing of steel or nickel provides a satisfactory solution to this problem, and the invention has given rise to improved sparking-plug performance. (British Patent No. 715,917.)

Other applications of chromizing include hot-forging die blocks; hinge-pins for joining the segments of "floating-roof" oil-storage tanks; filter screens for oil wells; annealing trays; soot-blower nozzles; boiler water level indicator bodies; hydraulic rams and spindles; steel quarls for oil-fired boilers; atomizer heads for the manufacture of powdered plastics; superheater tube spacers and supports; chain rollers for bottle pasteurizer plants; and foundation bolts and other components for hydro-electric projects in which chromizing is required to counteract the corrosive action of acidic peaty water.

It will be observed from the foregoing that the chromizing of steel components offers many advantages. The process provides an inexpensive method of imparting to the steel articles surface properties which are normally obtainable only by the use of highly priced alloys. Consequently, the process represents a valuable contribution in bridging the gap between normal qualities and the expensive corrosion and heat-resisting steels manufactured by the Group.

Modern Paints and Their Application

(*Continued from page* 121)

heavy components; and (3) plunge dipping where the articles to be painted are thrust manually into the paint and hung on a conveyor or drip rack. The rheological requirements of the types of paint for ideal performance differ considerably, but it is frequently possible to use the same paint for methods 2 and 3.

Spray painting is the most widely used industrial method. A recent development, the hot-spray process, utilizes the fact that paints decrease in viscosity at elevated temperature and heat is used as an alternative to thinners to facilitate the spraying of relatively viscous paints. More paint may be applied per pass of the gun than is possible by conventional cold spray methods, and where a number of coats are normally applied considerable saving of time, and consequently labour costs, may be effected by its use.

The most recent development in spray painting is the airless spray method in which the paint to be applied is heated, as with the orthodox hot-spray process, and is then forced at a pressure of some 600 lb. per sq. in. at the elevated temperature to the gun where the operator upon pressure of the trigger control releases the material through a small fixed nozzle. The speedy release of the high pressure at the point of eflux causes a complete breakdown of the liquid state, literally exploding into the atmosphere and thus achieving the same degree of atomization as has hitherto been achieved only by the use of large quantities of air. This results in more control over the passage of the atomized paint to the job with very little spray dust and over-spray. The saving in paint is considerable but specially formulated paints are necessary for use with this equipment.

It is not claimed that airless spray will displace the conventional air spray, and indeed for many users the initial cost of the plant will preclude its consideration, but it may well be that this method of applying paint will prove to be a major advance in paint application.

The same remarks may apply to steam spraying, in which steam replaces air as the atomizing medium and by which, it is claimed, that due to steam contracting upon cooling, spray dust is virtually eliminated and the spray particles are directed to the object to be sprayed and form on the surface rather than bouncing off it. This particular method is being investigated in America but so far as is known the method is not yet available in this country.

METAL FINISHING RESEARCH

Plans Announced for Extensions to Metallurgy Department of College of Technology, Birmingham

THE Department of Metallurgy of the College of Technology, Birmingham, moved from the old buildings at Suffolk Street last autumn, having been residence in there for over sixty years.

The present accommodation for metallurgy at the new Gosta Green buildings is located on the ground and lower ground floors and laboratories occupy a total area of about 15,000 sq. ft. An additional 10,000 sq. ft. will be available when the remaining portions of the college buildings are completed in two or three years time.

The department is among the largest metallurgical schools in the British Commonwealth, with a student population of about 400 taking metallurgy as their main subject, together with 300 engineers and others who take metallurgy as a subsidiary subject.

Three main types of courses of study in metallurgy are provided, *i.e.*, sandwich courses in metallurgy leading to the Dip. Tech.; degree course leading to the B.Sc. London (External) Honours Degree in Engineering (Metallurgy); the college associateship course incorporating the National Certificates and membership of the Institution of Metallurgists examinations.

The college has recently been designated as one of the eight Colleges of Advanced Technology. With this advance in status, the work of the department may be expected to expand at more advanced levels. Thus the sandwich-course students will be candidates for the new "Dip. Tech" qualification which has been instituted by the National Council for Technological Awards. Additionally the research work of the department is expected to expand very considerably, together with the institution of a number of short courses in advanced work of general interest to the metallurgical industries.

The full-time teaching staff numbers twelve. In addition there are thirty visiting lecturers and assistants who help mainly with the evening classes. The present teaching staff is to be augmented shortly by the appointment of two Readers, the one in physical metallurgy and the other in industrial metallurgy. These two new appointments will be primarily directed towards the furthering of research work.

A further 10,000 sq. ft. of accommodation is planned in the extensions now being built. This will be used for: a corrosion and protection laboratory; a metal-finishing laboratory; and research and project laboratories.

Bright Nickel Plating

(*Continued from page* 117)

intimately connected with the ability of the brighteners to give up doublets of electrons. However, this set of conditions, although "essential", is not "sufficient"[27].

It is thought that in the cathodic film there ought to be present, on the completion of the process of brightening, particles of a nickel complex and, more specifically, a complex having unpaired electrons and, hence, a specific paramagnetism, as could exist with a complex of the tetrahedral type.

It is this last condition which, in the last analysis, represents the specific region in which bright nickel is obtainable.

It will be the object of experiments in progress at the present time to provide confirmation of these hypotheses. Experimental evidence alone, in fact, will constitute the beacon which will guide our small craft, almost lost as it is in the ocean, safely into port.

This, our conclusion, may thus be regarded not as an arrival but, rather, merely as a stage along the road to that greater clarity in ideas which has been the object of our enquiry into bright nickel plating. It will then perhaps not have appeared entirely useless to have tried so high the patience of our readers!

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FINISHING
NEWS REVIEW

Metal Finishing Conference

Strong Programme Arranged For Brighton Meeting

THE Annual Conference of the Institute of Metal Finishing is to be held this year at the Grand Hotel, Brighton from April 10 to 12. The broad pattern of the Conference will conform very largely with that established in past years, and the arrangements include a number of works visits and social functions in addition to a comprehensive programme of technical papers. Particularly noteworthy in connexion with this year's Conference is the number of papers of general and organic-finishing interest included in the programme, as distinct from those of interest only to electroplating specialists. The programme, details of which appear below, shows every sign of having been drawn up with a proper regard for the fact that metal finishing as a technical subject should be treated on the broadest basis.

PROGRAMME

Wednesday, April 10, 1957

9.30 a.m.—Official Opening of Conference by His Worship the Mayor of Brighton, followed by 1*st Technical Session:*

(*a*) "An Investigation into the Mechanism of Levelling in Electrodeposition", by S. A. WATSON and J. EDWARDS.

(2) "The Influence of Periodic Reversal of Current upon the Surface Roughness of Electrodeposited Copper", by A. HICKLING and H. P. ROTHBAUM.

1.00 p.m.—Luncheon.

2.15 p.m.—*2nd Technical Session:*

(3) "Colour Anodizing", by A. W. BRACE.

(4) "Metal Coatings Produced from Powder by Peening", by G. H. JENNER.

(5) "Electrodeposition of Tin as a Bright Coating", by A. M. HARPER, A. MOHAN and S. C. BRITTON.

8.00 p.m.—Reception and Dance by invitation of the Mayor and Corporation of Brighton at the Hotel Metropole.

Thursday, April 11, 1957

9.15 a.m.—*3rd Technical Session:*

(6) "A Contribution to Knowledge of Cathode Polarization Phenomena of Nickel", by R. PIONTELLI and G. SERRAVALLE.

(7) "Change in Fatigue Limit on Chromium or Nickel Plating with Particular Reference to the Strength of the Steel Base", by C. WILLIAMS and R. A. F. HAMMOND.

(8) "A New Instrument for the Continuous Measurement of Stress in Electro-deposits", by T. P. HOAR and D. J. ARROWSMITH.

1.00 p.m.—Luncheon.

2.15 p.m.—*4th Technical Session:*

(9) "Adhesion of Surface Coatings", by W. D. MAY, N. P. D. SMITH and C. I. SNOW.

(10) "Advances in Booth and Oven Design", by A. L. NEWCOMB.

Works Visits: Alternative visits, by kind invitation of the directors, to either Underwood Business Machines Ltd. or Allen West and Co. Ltd.

8.15 p.m.—The Hothersall Memorial Lecture, delivered by Dr. U. R. EVANS (Cambridge University).

Friday, April 12, 1957

9.15 a.m.—*5th Technical Session:*

(11) "Application of Finishing Materials at Controlled Temperatures", by J. MUIRHEAD.

(12) "Airless Spraying", by T. COWLARD.

(13) "Automatic Spraying", by J. WEBB.

(14) "Aerosol Spraying", by E. E. V. SHARPE.

1.00 p.m.—Luncheon.

2.15 p.m.—*6th Technical Session:*

(15) "Recent Developments in the Cleaning of Intricate Mechanisms", by H. SILMAN.

(16) "Automatic Control in Relation to Metal Finishing", by J. W. CUTHBERTSON and J. E. PARTON.

7.00 p.m.—Reception by the President and Mrs. Hammond, followed by Conference Dinner and Dance.

Ladies' Programme

For the entertainment of ladies during the Conference period, a number of events and outings have been planned. These include a conducted tour of the Royal Pavilion, a visit to Preston Manor, a coach drive *via* Arundel Castle, including a visit to Petworth House, a Mannequin parade, and a demonstration of flower arrangement.

Brochures giving full details of the Conference and application forms for participation have been circulated to all members of the Institute, and further copies can be obtained where others interested in attending the Conference on application to the Conference Secretary, Institute of Metal Finishing, 32 Great Ormond Street, London, W.C.1.

B.I.S.R.A. "OPEN DAYS"

SINCE the earlier announcement of the forthcoming "Open Days" at B.I.S.R.A.'s Swansea laboratories, it has been found necessary to adjust the original dates slightly. The event will now be held on Wednesday, June 19, and Friday, June 21. One of the most important of the displays and demonstrations to be mounted will be the P.V.C.—steel laminate project, and the recently installed pilot line is already producing limited quantities of this material.

SAFE-TRANSIT PROGRAMME FOR ENAMELLED PRODUCTS

Introduction by Vitreous Enamel Development Council

ONE of the important tasks which the newly-formed Vitreous Enamel Development Council are undertaking is the initiation of a programme to improve the packing of vitreous-enamelled products to minimize damage in transit.

This will be conducted on the line of the outstandingly successful Safe Transit Programme adopted in the United States. There, very high losses from damage in transit were reduced to such a marked degree that from being a daily hazard it is now almost unheard of for loss to be sustained in this manner. It goes without saying that such a programme can save industry enormous sums of money apart from the improvement which must result in customer relationship.

The essence of the Safe Transit Programme is that close co-operation is maintained between specialist companies manufacturing package materials and the manufacturers of the vitreous-enamelled products. Packs designed specifically for a particular product are rigorously pre-tested by special machines which simulate the type of conditions most likely to cause damage such as accidentally dropping a package, violent shunting of a goods-train, sharp braking of a delivery truck or damage from some other article falling on the package.

Apart from the obvious savings such a programme can bring in cutting down the dead loss of replacement, insurance companies are expected to give preferential rates for enamelled products packed in materials or containers approved by the Safe Transit Programme testing house.

Further details of the Safe Transit Programme will be released by the Vitreous Enamel Development Council at their forthcoming General Meeting to be held at the beginning of March at the works of Ernest Stevens Ltd., Cradley Heath, Staffordshire, where facilities for holding the meeting have been very kindly offered by Mr. Darryl Baldwin, director and general manager of the company.

MUSEUM PIECE

THE original surface grinding machine which spurred the founding of the Abrasive Machine Tool Co. of East Providence, Rhode Island, will soon be a valuable museum item. The company president, Mr. Norman D. MacLeod, announced that the Abrasive No. 3 has been sent to the Smithsonian Institute in Washington, D.C. There it will be on permanent display in the Division of Engineering.

Built in 1916, it was the first machine tool of its kind to utilize a solid one-piece casting frame with the motor mounted on the inside of the machine. These two features improved the machine's durability, greatly increased its efficiency and precision and added to its safety.

For the Abrasive Machine Tool Co. the new design meant the founding of a prosperous business producing a broad line of precision surface grinders, face grinders and grinding accessories.

The original Abrasive plant operations were begun on its present site in East Providence, Rhode Island, in 1917. This plant had 6,000 sq. ft. of floor space and eight employees. Today, floor space totals 65,000 sq. ft. and employees number over one hundred and fifty. The company now has sales representatives throughout the United States, Canada, South America, Europe, Asia, and Africa.

MEMORIAL AWARD

THE Administrators of the Sir George Beilby Memorial Fund, representing the Institute of Metals, the Royal Institute of Chemistry and the Society of Chemical Industry, have made an award from the Fund for 1956, of one hundred and fifty guineas to R. W. Kear, F.R.I.C., M.Inst.F., in recognition of his work on the behaviour of fuel impurities in combustion processes, with special reference to the role of sulphur, chlorine and alkalies in corrosion and deposit formation by flue gases in combustion appliances.

Awards from the Fund are made to British investigators in science as a mark of appreciation of distinguished work, particularly in such fields as fuel economy, chemical engineering and metallurgy in which Sir George Beilby's special interests lay. In general, the awards are not applicable to more senior investigators but are granted as an encouragement to relatively young men who have done independent work of exceptional merit over a period of years.

CONGRESS ON SURFACE ACTIVITY

THE first International Congress on Detergency was held in Paris in 1954. It was agreed then that the second Congress would be held in England and, under the broader title of the Second International Congress of Surface Activity. This will take place in London from April 8 to 12.

The President of Honour is Lord Brabazon of Tara and Sir Eric Rideal, F.R.S., is president. The organizing committee, of which Dr. L. H. Lampitt is chairman, includes representatives with industrial and academic interests.

A comprehensive programme of lectures has been arranged by a committee under Dr. J. H. Schulman, head of the Department of Colloid Science at Cambridge University. Authors of these papers come from 18 countries and the subjects cover the full field of surface activity. A programme of works visits has been arranged by a committee under Mr. M. K. Schwitzer, and a reception and a banquet have been organized.

The papers will all be printed and circulated to members of the Congress in advance. Discussion of the papers will take place in groups after a brief introduction by the authors.

There are few industries which are not served by surface activity compounds or whose problems do not involve surface activity phenomena in one way or another. The papers to be read at this Congress constitute a comprehensive survey of surface activity and will be a worthy reference for many years to come. Industrial chemists will find it of great help in dealing with practical problems.

The membership fee for the Congress is £4 and application forms or further details may be obtained from the Hon. Secretary, IInd International Congress of Surface Activity, 14 Belgrave Square, London, S.W.1.

Vitreous Enamel in Germany

VITREOUS-ENAMELLED "tiles" and sheets, etc., were featured at the exhibition "Konstruiren in Stahlblech", held recently at the Technische Hochshule in Hannover, Germany. Sheets in a wide range of colours, and with flat and corrugated surfaces were on show, together with examples of their applications on buildings, etc.

Meetings of the Month

MARCH 18

Institute of Metal Finishing (London Branch). "Recent Developments In Copper Plating", by D. E. Weimer at the Northampton Polytechnic, St. John Street, London, E.C.1, at 6.15 p.m.

MARCH 21

Institute of Vitreous Enamellers (Northern Section). "Measurement and Control of Temperature and pH", by M. A. Stratton, at the Queen's Hotel, Piccadilly, Manchester, at 7.30 p.m.

Society of Chemical Industry (Corrosion Group). All-day symposium on the "Corrosion of Metals in Buildings", at 9.30 a.m.

MARCH 26

Metal Finishing Association Luncheon Meeting. Address by William Blackwell, president of the National Union of Manufacturers on "A Changing World", at the Farcroft Hotel, Rookery Road, Handsworth, Birmingham 21.

MARCH 27

Institute of Metal Finishing (Organic Finishing Group). "The Protection of Metal with Tannins", by E. Knowles, B.Sc., and T. White, B.Sc., A.R.I.C., Ph.D., Joint meeting with the London section of the Oil and Colour Chemists' Association at the Royal Society of Tropical Medicine and Hygiene, 26 Portland Place, London, W.1, at 7 p.m.

MARCH 28

Institute of Vitreous Enamellers (Midland Section). Annual General Meeting followed by "The Serviceman's Aspect of Vitreous Enamelling", by D. Mill, at the Birmingham Exchange and Engineering Centre, at 7.30 p.m.

MARCH 29

Institute of Metal Finishing (Sheffield and North-East Branch). "Silver Plating—Art or Science", by T. P. Hoar, M.A., Ph.D.(Cantab), B.Sc. (London), F.R.I.C., F.I.M., at the Grand Hotel, Sheffield, at 7 p.m.

APRIL 3

Society of Chemical Industry (Corrosion Group). "The Protection of Structural Steel Against Corrosion", by J. C. Hudson, at the Technical College, Newport, Mon. Joint meeting with the South Wales section at 7 p.m.

APRIL 4

Institute of Metal Finishing (North-West Branch). "Some Aspects of Fuel Economy in the Metal-Finishing Industry", by G. Gill, M.I.Plant E., M.Inst.F., at the Engineers' Club, Albert Square, Manchester, at 7.30 p.m.

APRIL 8

Society of Chemical Industry (Corrosion Group). Spring Lecture "Corrosion Researches of Professor Piontelli and his Associates at Milan", by R. Piontelli, at 14 Belgrave Square, London, S.W.1, at 6.30 p.m.

APRIL 9-13

Institute of Metal Finishing. Annual Conference at the Grand Hotel, Brighton.

TRADE and TECHNICAL PUBLICATIONS

"Pretreatment and Finishing Plant": This catalogue, published by Stordy Engineering Ltd., Goldthorne Hill, Wolverhampton, describes the range of the company's products for finishing and pretreatment. It includes specialized thermal plant incorporating all ancillary equipment, control gear and mechanical-handling apparatus.

Well illustrated, the catalogue shows paint-spray booths; continuous pretreatment and varnishing units; continuous cleaning, pickling, phosphating and drying units; batch-loading-type metal pretreatment and drying equipment; spray metal pretreatment plant; automatic paint dipping and stoving ovens; flow section coating; electrostatic spray booths, etc.

It states that the standard now called for in modern finishes demands not only close control of finishing materials but also pretreatment of the base metal which has to receive the paint finish. The pre-treatment process varies depending on the type of work and degree of final finish required, and also on the quantity and size of the workpiece.

The use to which the coated article will be put, determines in some measure the method of paint application, and the descriptions of actual working plants given cover the majority of the various methods employed.

"Electro-Deposition of Metals": This 28-page reference book on the electro-chemical deposition of metals has been published by Fescol Ltd., North Road, London, N.7, as part of a comprehensive information folder.

The book includes a detailed technical section devoted to the properties of nickel and chromium, supported by graphs and photographs; and tables listing the resistance of both metals to corrosion have been specially compiled from recognized authorities. A short history of the company and an outline of the services they offer is also included, together with notes on the preparation of articles for "Fescol"-izing.

Although the Fescol process was originally developed to make good deficiencies caused by wear and tear, or incorrect machining, it is now being employed mainly for new components. The process enables new products which have a comparatively cheap and easily-worked base to be improved by depositing, electrochemically, a surface which possesses certain special qualities such as resistance to oxidation, abrasion, etc.

The folder contains also a series of five leaflets, each of which cover the applications of the Fescol process to a specialized field, including hydraulic machinery; metal industries; paper and printing trades; machine-shop production; and the textile industry.

Copies of the complete folder are available from the company on application.

"Zinc Rich Primer": A brush-applied cold-galvanizing process is described in this leaflet published by British Paints Ltd., Portland Road, Newcastle-on-Tyne 2.

This primer makes use of the now well-established principle in coatings for ferrous metals whereby metallic zinc powder is bound to a surface with a minimum quantity of binder. The film so produced is electrically conducting, and when applied to clean metal surfaces the particles of zinc are in electrical contact with each other and with the underlying metal. In this way the primer functions not only as an excluding barrier coat in the same way as an ordinary paint film, but it also acts as an anodic and electrically conducting coating.

The leaflet also gives information on the uses and applications of the primer.

Industrial Process Plants: The latest leaflet produced by Heat and Air Systems Ltd., Coastal Chambers, 172 Buckingham Palace Road, London, S.W.1, describes a comprehensive variety of industrial process plants designed by the company for a number of different industries.

These installations, each of which is briefly described in the leaflet, include motor-car-body finishing plant, flour-milling machinery, agricultural machinery and tractors, service vehicle cleaning and painting installations, pre-treatment processes and oven heaters.

TIN RESEARCHES IN 1956

Metallurgical and Chemical Developments

THE "Report of the Tin Research Institute for 1956" will interest chemists as well as metallurgists. The new discoveries in the methods of synthesizing organotin compounds will, it is thought, open the door to many industrial applications for this class of compound in the control of fungi in many industries and in agriculture.

The metallurgical researches have also achieved many successes. The new aluminium-tin bearing alloy can now be bonded to steel strip by a simpler method than previously. A tin-base alloy of special composition has proved its excellence for high-speed die-casting into the tips for ball pen nibs.

"Bright" tin coatings by the electrodeposition method have long been one of the Institute's objectives. In the rather guarded terms of the Report " . . . some results have been obtained which give promise that (bright coatings) may be achieved."

The Institute has continued to disseminate information concerning all its researches and developments, together with advice and help, to tin users throughout the world. As part of this work the Institute's "Pewter of To-day" Exhibition was on show in three European countries during the spring and since midsummer it has been touring the United States. Including the Headquarters at Greenford, just on the border of London, there are now nine centres of information about tin in Europe, Canada and the U.S.A., all part of the same organisation.

Installation of Spray Unit for Vitreous Enamel

THE installation of a Ransburg electrostatic spray unit for the application of vitreous enamels is being carried out at the works of Escol Products Ltd., Swains Road, London, S.W.17.

This installation which will be the first of its type in Europe is being carried out in collaboration with Henry W. Peabody (Industrial) Ltd., who are the representatives for this process in the United Kingdom and Western Europe.

Escol Products Ltd. will be acting as consultants to Henry W. Peabody Ltd. to assist and give technical guidance in connexion with the preparation and application of vitreous enamel by this method.

Development work on frits and the preparation of materials will take place at the works of Escol Products.

Demonstrations and service work will be carried out on potential users' products in this installation and the facilities available at Escol Products and Stewart and Gray Ltd., will enable work to be carried out not only on the application of the vitreous enamel, but also the drying and fusing. Facilities will also be available for the preparation of frits, as desired.

Long Service

Commencing with the former Wilmot Manufacturing Co. in 1920, and continuing when Wilmot Breeden Ltd. was formed in 1927, Mr. Arthur William Bosley has just retired from service with the company. Mr. Bosley was in charge of plating from the outset, commencing with cold and still plating processes, and was responsible for the introduction to the company of hot and agitated solutions, and also for chrome plating, advancing to auto plating.

As foreman plater, he was responsible for the metal and chrome plating of the first bumper to be produced in England. Over the years spent with the company, Mr. Bosley has justly earned a very great reputation in the practical plating field, and it is agreed by all who have ever come into contact with him that his experience and persistent endeavours have been the decisive factor in solving many difficult plating problems.

Electrical Engineers, Exhibition

THE 1958 Electrical Engineers, Exhibition will again be held at Earls Court and the dates will be from March 25 until March 29 inclusive. Since Easter is earlier than normal in 1958, the dates of the Exhibition have also been brought forward.

This early announcement has been made by the Electrical Engineers (A.S.E.E.) Exhibition Ltd., because of the large number of enquiries for stand space in 1958, which have already been received.

All stand space for the 1957 Exhibition, which will be opened by Lord Hailsham, Minister of Education, on Tuesday, April 9 at Earls Court, has been taken up. Almost 400 exhibitors will be showing this year, making it the largest exhibition of its kind ever held.

OBITUARY

Matthey: The death has occurred of H. W. P. Matthey, chairman of Johnson, Matthey and Co. Ltd., at the age of 80.

Griffiths: A. E. Griffiths, founder and chairman of A. E. Griffiths (Smethwick) Ltd., has died.

TECHNICAL AND INDUSTRIAL APPOINTMENTS

The following changes in the board of directors of **Griffin and George Ltd.,** the laboratory furnishers, are announced:—

Mr. Ronald McKinnon Wood, O.B.E., has asked to be relieved of his duties as chairman of the company, in view of the important public duties he will assume in the near future as chairman of London County Council. Mr. H. R. Bettinson, M.C., hitherto vice-chairman, will for the time being act as chairman of the board. Mr. Norman McKinnon Wood has been appointed vice-chairman and relinquishes his appointment as managing director. Mr. Norman Trepte has been appointed managing director.

* * *

Dr. J. S. Gourlay, formerly joint managing director of the plastics division of **Imperial Chemical Industries Ltd.,** has been appointed chairman of the paints division of the company.

* * *

Dr. V. G. W. Harrison, F.Inst.P., F.R.P.S., F.I.E.S., has been appointed director of research of the **Printing, Packaging and Allied Trades Research Association.** He succeeds Dr. G. L. Riddell, F.R.I.C., who is leaving the Association to join Albert E. Reed and Co. Ltd., as head of their expanding packaging research and development division. Dr. Harrison, for the past nine years in charge of PATRA'S optics laboratory, takes up his new appointment on April 1. He is 45 and has been with PATRA since 1937.

* * *

The **Mond Nickel Co. Ltd.** announces that Mr. L. K. Brindley, deputy chairman of the company and of Henry Wiggin and Co. Ltd., and Mr. A. Parker Hague, a director of the two companies, having reached retirement age, have relinquished their appointments.

Latest Developments in PLANT, PROCESSES AND EQUIPMENT

Mop dressing Cabinet

THE application of coatings of abrasive powder to felt or fabric mops is very frequently an operation which is carried out without any great degree of care or control with the result that the performance of the mop, both with regard to its life and the quality of the finish which it is capable of yielding are both less than they might otherwise be. The availability of a mop-dressing cabinet manufactured by A. E. Griffiths (Smethwick) Ltd., Booth Street, Birmingham 21, should make a significant contribution towards improving this state of affairs. The cabinet (Fig. 1) is made in three sizes having two, three or four compartments and is available in any colour with chromium plated fittings.

Heating can be by either steam or electricity and is thermostatically controlled in both the lower pre-heating compartment and the upper curing compartments. In Fig. 1 the cabinet is shown with the abrasive trays pulled out (note the heaters below these). Adjacent to these are the thermostatically controlled pre-heating compartments, while above are the glue pots on controlled heaters. The upper part of the cabinet is taken up by compartments where the mops are cured at a controlled temperature after coating with abrasive.

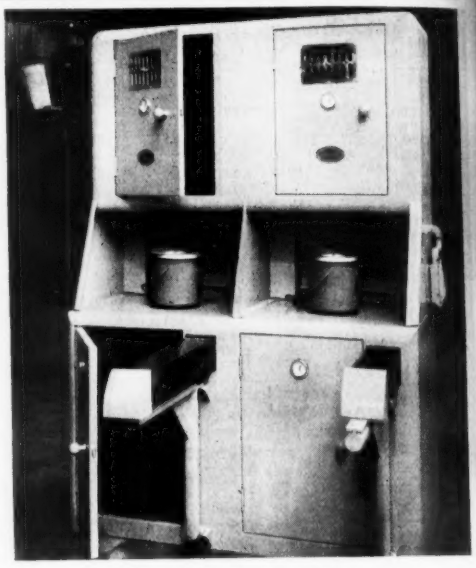


Fig 1. *Mop-dressing cabinet.*

Surface Roughness Scales

THE assessment of surface roughness by touch has been made very much more exact by the provision of a range of roughness scales in the form of stainless steel specimens finished to a carefully controlled degree of roughness. Sets of such scales have been available for some time from Rubert and Co. Ltd., Levenshulme, Manchester 19, who have now added to their range by bringing out an improved pocket-size set No. 24 Mark II. This comprises twelve stainless-steel specimens each 1 in. x $\frac{3}{8}$in. and finished according to B.S. 1134: 1950 to a range of surfaces between 2 and 500 micro-in. CLA. In order to eliminate discrepancies arising from differences in texture due to the use of different surface treatments, these finishes are produced either by lapping, grinding, milling or shaping, as indicated on each scale.

Axial-flow Fans in P.V.C.

THE introduction of a range of axial-flow fans constructed from rigid P.V.C. has been announced by Horwitch Smith and Co. Ltd., Pensnett, Staffs. These fan units are mounted directly into ventilation ducting to give maximum extraction efficiency. The motors are in line and encased in a P.V.C. housing ensuring minimum interruption of the air flow and complete protection of the motor. The impeller is all rigid P.V.C. construction built around a cast aluminium core. The impeller body is removable for easy access to the motor housing.

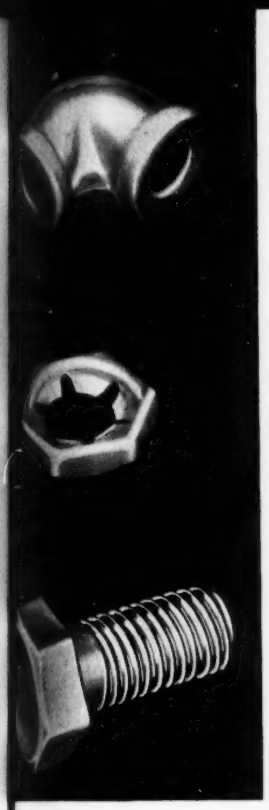
Rigid P.V.C. is resistant to a wide range of fumes and vapours at temperatures not exceeding 78° C (158° F), and the fans are available in a wide range of sizes and duties.

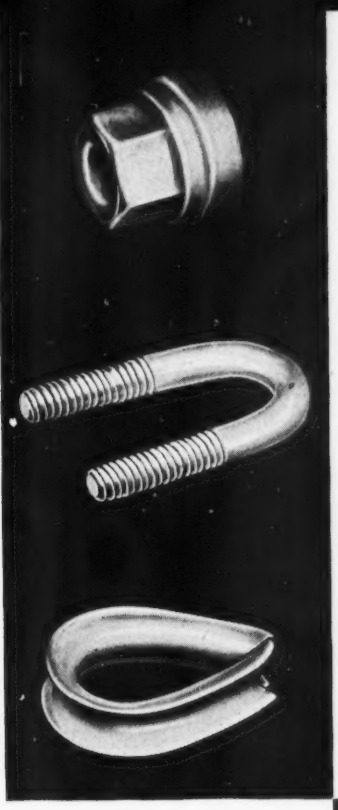
Metal Rich Primers

A RANGE of metal-rich paints under the general trade name of "Metalife" has been announced by Southern Metalife Ltd., Harrogate, Yorks. The action of these paints is based on the now widely-recognized principle that a coating containing more than 90 per cent. of zinc or other metal less noble than iron and steel is capable of affording sacrificial protection to the ferrous base to which it is applied.

The "Metalife" series is available in four grades: PFU for general use where the coating is not subject to severe abrasion, contact with strong

(*Continued in page* 134)





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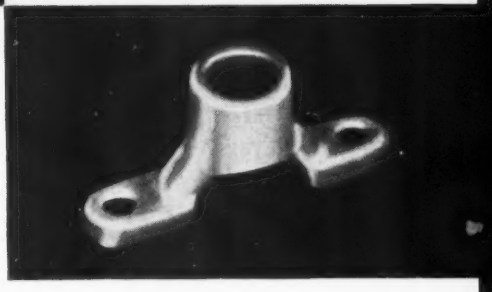


For Hot Galvanizing

Through modern pre-occupation with the large and spectacular, we often forget the vital importance of the little things—the nails, washers, nuts and bolts which keep the parts together. These, not less than the main steel structures need hot galvanizing—the best way of ensuring long term protection at a reasonable cost. Few articles are too small to be treated. Up-to-date methods of centrifugal galvanizing allow small parts to be given a heavy and uniform coating of zinc. Threads as fine as those on a 5/16″ diameter bolt can be galvanized ready for use—with no subsequent cleaning required. Whatever the size of a part, large or small, it can usually be galvanized.

Hot Dip Galvanizers Association

The Hot Dip Galvanizers Association, a non-trading body, welcomes enquiries. Write to 34 Berkeley Square, London, W.1 Tel. Grosvenor 6636

Member of the Zinc Development Association

solvents or chemicals or exposure to temperatures in excess of 212° F. ;ATR is for use in applications where temperatures are encountered up to 550° F. "Metalife" wet has similar properties to PFU but is specially formulated for use on wet iron and steel surfaces. "Metalife" heavy duty is for use under conditions of severe abrasion or where strong solvents or chemicals are likely to be encountered. It is unaffected by temperatures up to 300° F. It requires the addition of a catalytic hardener immediately before use. Metakote sealer, which provides a resistant skin, is available for use over a heavy-duty coating where particularly aggressive conditions are likely to be encountered.

Automatic Spray Painting

A NUMBER of modifications and improvements have been carried out on the Bullows-Berridge automatic spray painting machines (Fig. 2) by the manufacturers, Alfred Bullows and Sons Ltd., Walsall, Staffs, in the light of experience gained in the three years since this equipment was first developed. These include:

The addition of a friction clutch to the camshaft drive which may now be adjusted to slip under overload conditions, preventing damage to the mechanism and providing greater safeguards for the operator.

Easy removal of the spray chamber from the machine for periodic cleaning.

Increase in the indexing range of the machine to give spindles at 3, 6, 8 and 12 in. pitch to give greater flexibility of operation.

Variable speed control, now fitted as standard equipment, giving a 3 to 1 output speed variation.

Facilities for conveyorizing the machines, using a special chain incorporating rotating spindles, to allow painted components to be stoved and cooled for unloading without further handling.

A wide range of ovens, flash-off and assisted cooling tunnels for use with the conveyorized machines, complete with temperature-indicating and controlling equipment and various safety devices.

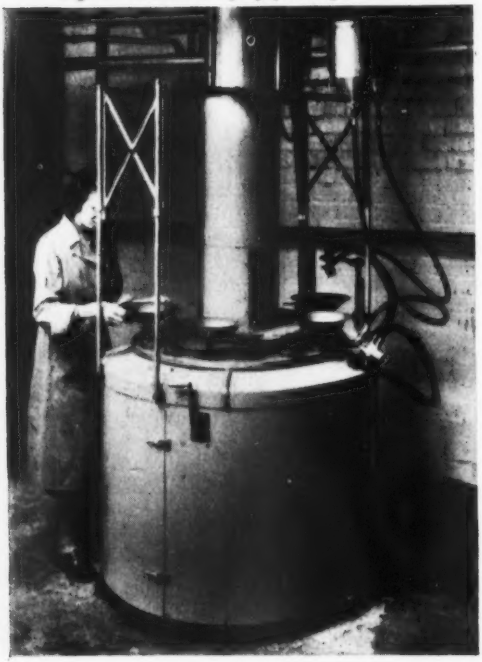
A novel take-up and drive unit for extended conveyors operating at high speeds which allows the conveyor not around the indexing machine to travel at constant speed.

A new method of article detection which may be operated manually, electrically, mechanically or electronically, according to the type of component and customer's requirements.

A range of standard traverses including vertical, horizontal, taper and arc spraying attachments.

Specially designed attachments for automatic loading, unloading and transfer operations where production quantities are very high.

Fig. 2.—Automatic spray painting machine.



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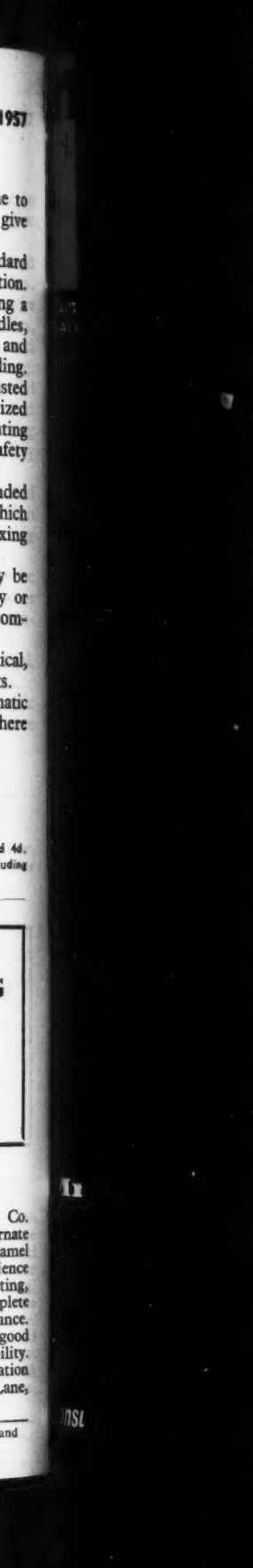
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